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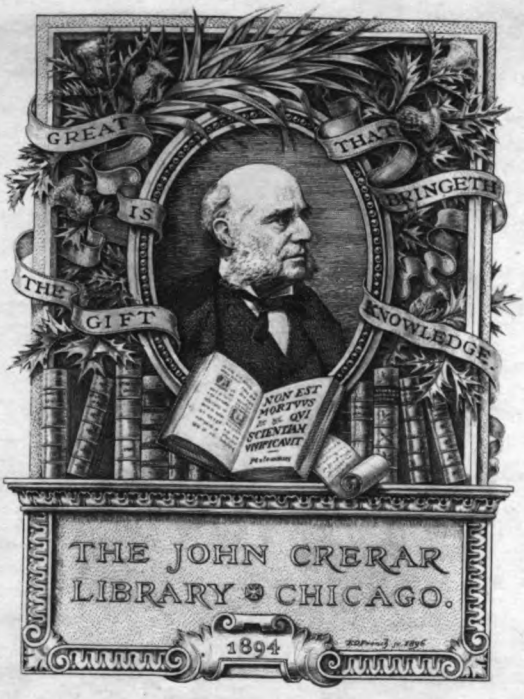

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Summary of Progress *of the* GEOLOGICAL SURVEY OF GREAT BRITAIN *and the* Museum of Practical Geology for the Year

1927

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PART I

LONDON:
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Department of Scientific and Industrial Research

Summary of Progress

of the

Geological Survey of Great Britain

and the

Museum of Practical Geology

for the Year 1927

PART I

With Report of the Geological Survey Board and Report of the Director

LONDON:
PRINTED UNDER THE AUTHORITY OF HIS MAJESTY'S STATIONERY OFFICE
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REPORT OF THE GEOLOGICAL SURVEY BOARD FOR 1927

TO THE LORDS OF THE COMMITTEE OF THE PRIVY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

MAY IT PLEASE YOUR LORDSHIPS.—

In accordance with our terms of reference, we, the Geological Survey Board, beg to submit our Eighth Annual Report on the work of the Survey and Museum.

1. We noted, with interest, the appointment (1st July, 1927) of a Royal Commission on the National Museums and Galleries to report on the legal position, organisation, administration, accommodation, the structural condition of the buildings, and general cost of the institutions containing the National collections situate in London and Edinburgh.

The Director of the Geological Survey and Museum gave evidence before this Commission on the 3rd November, 1927. In view of the primary importance of adequate accommodation in London for the Museum of Practical Geology and the Headquarters of the Survey, we have welcomed with special satisfaction the following answer by the Under-Secretary of State for the Home Department to a question in the House of Commons on the 22nd December, 1927 :—

> "The Royal Commission on the National Museums and Galleries has represented that the present conditions in Jermyn Street are unsatisfactory from every point of view, and that the transfer of the Geological Museum to an appropriate site in South Kensington should be made at the earliest convenient moment. The Chancellor of the Exchequer and my Noble Friend endorse this view, and hope to give effect to it as soon as financial circumstances permit."

We hope that the financial circumstances will allow of progress being made in this urgent matter at an early date.

2. We understand that premises known as Southpark, 19 Grange Terrace, Edinburgh, have been purchased to provide accommodation for the headquarters of the Scottish staff when the lease of the present office of the Survey (33 George Square, Edinburgh) expires in May, 1928. We believe the new premises to be very suitable for the purpose.

Two other changes in the District Offices have been arranged :—

(1) The Manchester Office is shortly to remove from 21 Albion Street to 272 Oxford Road, Manchester, and

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(2) The Whitehaven Office has been closed and the headquarters of the Cumberland unit moved to London.

The Manchester change was necessitated by the expiry of the lease and the Cumberland change was considered opportune as the survey of the coalfields in the district around Whitehaven and Maryport has now been completely revised.

3. The detailed statement of work done by the Survey in 1927, which is given in the Director's Report for the year, shows that the various items of the pre-arranged programme have been carried out. Notwithstanding two vacancies in the grade of 'Geologist' this progress has been coupled with a large amount of attention to the many topics of scientific and economic interest which inevitably emerge in the course of a year.

We are gratified by the smooth working of the arrangements for maintaining a continuous record of additions to information as to the geology of mines.

The ability and zeal of individual members of the staff of the Geological Survey are recognised and appreciated by geologists and others whose work or interest leads to personal contact with them. The alertness and the elasticity of the Survey as a public service may be illustrated by the advance it is making in the methods of presentation of results in its maps and memoirs, and, again, by the scientific enquiry it is conducting on the uses of the Eötvös Balance—experimental investigations bearing on possible aids in geological surveying.

4. The Field Units have been engaged on surveys of eleven districts prescribed by the programme approved for the year, viz. :—

(*a*) London and Southern District (primary six-inch survey).
(*b*) Midlands District (primary six-inch survey).
(*c*) Yorkshire District (revision of six-inch survey).
(*d*) Lancashire District (revision of six-inch survey).
(*e*) Cumberland District (revision of six-inch survey).
(*f*) Northumberland and Durham District (revision of six-inch survey).
(*g*) Ayrshire, Dumbartonshire and Stirlingshire (revision of six-inch survey).
(*h*) Peeblesshire and Midlothian (revision of six-inch survey).
(*i*) Fife and Kinross (revision of six-inch survey).
(*j*) North Highlands (primary six-inch survey).
(*k*) Orkney Islands (primary six-inch survey).

Details of the work carried out by each of the above-mentioned Field Units will be found in the 'Summary of Progress.'

A large amount of revision of the six-inch geological mapping was carried out in the Merthyr Tydfil sheet with a view to the production of a new edition of the memoir on this area. Revised editions of several of the relevant six-inch sheets are now in the press.

5. The Director's Report shows that the total area of ground mapped in 1927 is somewhat smaller than that recorded in some

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previous years. Variations in extent of survey often arise in respect of differences in the geological structures under investigation, or in the extent to which areas had previously been investigated. So far as the 1927 mapping is concerned variations due to such causes may be said to have averaged out. But the very full programmes of field-work carried out during the last two or three years have produced an increased crop of data ripe for publication. Hence it has been found advisable for the Scientific Staff to devote rather less time than usual to the accumulation of new observations and more to the preparation for publication of maps and memoirs on areas recently surveyed. We regard this course as wise ; it aims at the prompt publication and issue of maps and memoirs; and in this and in other ways it expedites the public use of the work of the Survey. As a result of this policy we are gratified to point to the large output of publication work of the Survey during the past year, while we are also glad to call attention to the satisfactory style in which memoirs are being produced and to the improvements now being effected in the production and reproduction of the maps.

A full list of the published matter appears in the Director's Report. In particular, we wish to mention (1) the new London District map, which should be very useful to schools and technical colleges teaching Geology in and around London, (2) the third and much extended edition of the memoir on the ' Oil-Shales of the Lothians '—a technical manual of recognised value, and (3) the annual ' Summary of Progress of the Geological Survey,' which is of increased importance to geological students now that so large a part of the volume is devoted to Appendices on matters of geological interest.

6. We are glad that the Director has found it possible to commence, in accordance with our recommendation of last year, a series of trials with the Eötvös Gravity Torsion Balance on known areas in Britain. The first of these trials was made on the underground extension of the Swynnerton dyke in Staffordshire and the results obtained were in every way satisfactory. A second test is now being carried out on a buried channel filled with Drift deposits in the Kelvin valley area, north-west of Glasgow. This survey has made good progress but was unfinished at the close of the year.

7. Additional memoirs on the water-supply of English counties are in preparation and in the press, and a volume on English Ball Clays has been written which will continue the series of Special Reports on British Mineral Resources.

8. We are pleased to record that Survey co-operation with the soil experts has continued throughout the year. Some practical problems were worked out near Scarborough during September at a joint meeting of soil experts and field geologists. An arrangement for supplying cheap photographic copies of Survey manuscript maps has also been instituted with a view to helping the agriculturists as well as to experiment with a new method of circulating geological information obtained by the Survey.

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A soil map of the Kilmarnock area and a chapter on 'Soils' for the Kilmarnock memoir have been prepared by Professor Berry, and will be published in due course.

9. It is satisfactory to note that under Section 23 of the Mining Industry Act, 1926, to which reference was made in our last year's Report, 108 notifications of proposed borings for minerals have been received up to the 31st December 1927. With a return of the Mining Industry to prosperity it is anticipated that this number will be considerably increased.

10. The programme of field-work for 1928 is :—

(*a*) primary mapping on the six-inch scale in the Midlands district (Shrewsbury sheet), in the south-east of England (Reigate sheet), and in the Orkney Islands ;

(*b*) revision of original six-inch mapping in the following coalfields and the adjacent areas :—Cumberland, Northumberland, Lancashire, Yorkshire, South Wales, Ayrshire, Fifeshire and Renfrewshire ;

(*c*) investigation of underground water supplies ; verification of bore records ; examination of mineral resources ; and application of geophysical methods of surveying.

F. G. OGILVIE,

Chairman.

16*th May*, 1928.

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SUMMARY OF PROGRESS OF THE GEOLOGICAL SURVEY AND MUSEUM FOR 1927

I. REPORT OF THE DIRECTOR

THE activities of the Geological Survey of Great Britain during 1927 were numerous and wide-spread. They may be said to include every part of Great Britain though not of course to an equal degree, as some areas are, from the point of view of economic geology, much more important than others. Enquiries are received daily regarding the geology of the whole country and its application to practical problems, and these are answered by reference to the published maps and memoirs, the great series of manuscript maps preserved at the English and Scottish headquarters, and the mass of accumulated records which have been acquired during a period of nearly a hundred years. But the new work which is done during each field season and prepared for publication during the winter is spread over the whole country so that much fresh information is being obtained from all quarters on a vast range of geological problems.

In the South of England, for example, survey work was carried on in Surrey; a water supply memoir on Sussex is in hand, also new maps and memoirs on Kent; mining records were obtained in Cornwall and Devon; a water supply memoir is printing on Somerset. In the Midlands there are memoirs printing or preparing on Wolverhampton, and Warwickshire water supply, and the Dudley and Shrewsbury Sheets are being revised. The Lancashire and Cheshire coalfields are being most thoroughly re-examined, and in Yorkshire the Huddersfield Sheet is passing through the press and the Glossop Sheet is being re-surveyed. Every development in the great Concealed Coalfield of Yorkshire is being recorded. In East Anglia new maps and memoirs are passing through the press. In Northumberland the coalfield around Alnwick, Morpeth and Newcastle is in hand and a complete re-survey is making progress. A considerable part of the Cheviot Hills was re-mapped. In Cumberland new maps of the important coalfields of Whitehaven and Maryport are being engraved and the Brampton Sheet has been completely revised.

In South Wales a new memoir has appeared on Abergavenny and a second edition of the memoir on the Iron Ores of the Forest of Dean. The Merthyr Tydfil memoir is at present undergoing revision. In North Wales the maps and descriptions of the country around

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Wrexham and Oswestry are approaching completion and publication.

In Scotland work continues in the Ayrshire coalfields and some revision has been made in Renfrewshire, Stirlingshire and Dumbarton. Some Lanarkshire coalfield maps are in the press and new maps are being published of Galloway and Kirkcudbright. A new memoir on Arran is printing. The revision of the coalfield of Fife is in hand and some work has been done in the Midlothian coalfield. The third edition of the 'Oil-Shales of the Lothians' has been published. The new map of the Stonehaven area is at the engraver. Central Sutherlandshire has been visited in order to obtain further information for the completion of the maps. Memoirs are in preparation on Tiree and Ardnamurchan and the primary survey has extended to the Orkneys.

Although during 1927 the activities of the Geological Survey have expanded in several new directions the general scheme of work has of necessity followed very closely those of previous years. On the whole perhaps a less area of ground has been surveyed or revised than usual, but on the other hand the standard and volume of publications have been fully maintained. These two departments to some extent counterbalance one another. It is periodically necessary to shorten field programmes in order to retain the staff for a longer time in the office to complete the proofs of their maps and the manuscripts of their memoirs. This is especially true of coal-field surveys where comparatively little information is to be obtained by an inspection of the surface of the ground, and much depends on a complete study of mine plans, bore records and shaft sections. These must be obtained at the cost of much search from the engineers and others who are in possession of them, and very carefully studied and compared before a knowledge of the underground structure is attained. A glance at the list of six-inch coalfield maps given on pages 12-15 of this report will indicate how much of this class of work has been undertaken during the year. At no period of its history has the Survey been so fully engrossed in coalfield surveys as at present. Every working unit except one is busily engaged in this task. As a relief, however, from the monotony of such work and to provide some of the younger geologists with different problems for investigation, a certain amount of ground, not coal-bearing, has been mapped, such as the Cheviot Hills and parts of Shropshire. In addition to the revision of work done long ago and no longer abreast of economic requirements the six-inch survey of ground not previously mapped was extended to the Orkney Islands, where three geologists of the English staff and one of the Scottish were engaged for three months and mapped a considerable area of comparatively simple ground.

Among the principal developments which indicate an advance in programmes and activities during the past year as compared with previous years the following may be mentioned:

(*a*) The inception of a programme of geophysical work by means

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of the Eötvös balance, which has kept a small party in the field for several months.

(*b*) The establishment of a regular system of registration of all bores and shafts notified under the Mining Industry Act of 1926 (see last year's *Summary of Progress*, pp. 25-28) and the inspection of all important bores. The journals are checked, specimens collected, and a full and accurate record obtained before the work is closed down.

(*c*) A new colour scheme has been devised for the well-known map on the scale of four miles to one inch. It is intended to abandon the old system of colour printing used for this map and to adopt that in which only seven stones are used, as has been done for some time with the one-inch maps of England and Scotland. In consequence it seemed advisable to alter the colour scheme in order to obtain the best results in the simplest possible way by the new process. The objects to be aimed at are (1) simplicity, (2) cheapness, (3) clearness, (4) contrast; and only by very careful consideration of different schemes can these results be obtained. The Index of Colours of the new map is published, and the first sheet of the series is now printing off. This is Sheet 11 (Derby and Sheffield area) which has always been very popular and has commanded a ready sale. Other sheets of this map will follow as the stock in hand is sold out.

(*d*) It is worth while also to mention that the sale of photographic copies of six-inch manuscript maps has been authorised. Only coalfield areas are published on the six-inch scale. Of other areas standard manuscript copies are prepared and deposited in the library for the use of the public who wish to consult them (see pp. 15-16). Hitherto it was only possible to obtain such maps by ordering a hand-drawn and coloured copy, and as these are expensive, costing often 40/- or 50/- each, the sale was very limited. Experiment has proved, however, that photographs from these six-inch maps on the scale of about three inches to one mile may be very useful, though much inferior to hand-coloured copies, and already there is a certain demand for these photographs. It is probable that they will be much appreciated by soil experts who are doing agricultural research work.

Field Work

The programme of field work continued that of 1926. The only new district to be opened out was the Orkney Islands, which were taken in hand on the completion of Caithness and Sutherlandshire in the previous year. The weather during the field season there was very good and rapid progress has been made. With the completion also of the South Ayrshire Sheet (Sheet 14, Scotland) some members of that unit were transferred to the district north and west of Glasgow, where all the coal-bearing strata were revised

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some years ago, but the whole of the one-inch map (Sheet 30, Scotland) has not yet been re-examined.

In the London district much work has been done in preparing new editions of some very popular maps such as Dover, Margate, Hastings and Dungeness, all of which have been sent to the engraver. The Aldershot Sheet is also engraving, and the Moreton-in-the-Marsh Sheet will soon follow. In East Anglia the Ipswich Sheet (207) has been published and Sudbury (206), Woodbridge (208) and Felixstowe (225) are at the engraver. In writing up the memoirs on these sheets the assistance of Professor Boswell and Mr. Osborne White has been obtained. Only the Aldershot Sheet, which is a very important one in many respects, has been completely re-surveyed on the six-inch scale. The others have obtained such revision as seemed absolutely necessary and could be given to them in the time available.

In the West Midlands the unit working under Mr. Cantrill has been engaged in six-inch mapping of the Shrewsbury area for the first time. That coalfield is comparatively unimportant, but the surrounding district is rich and varied in its geological features and is classic ground for the student of the older Palaeozoic and pre-Cambrian rocks of England. This staff unit has had an exceptionally large amount of publications passing through the press. Mention must also be made of the work of Dr. Robertson in South Wales. Accompanied for a time by Mr. John Pringle and Dr. Crookall he has examined a large part of the Merthyr Tydfil Sheet (231) in preparation for a new edition of the memoir on it which has been out of print for a number of years. As in the Abergavenny area, which he examined last year, it is probable that some of the current six-inch coalfield sheets will be issued in a revised form.

The Lancashire and Yorkshire units have lent certain members of their staffs for part of the year to engage in the primary survey of the Orkney Islands. The former is engaged principally in the difficult work of bringing out a new edition of the Manchester Sheet, a district of considerable complexity and obscurity. The Wigan Sheet (84) has been taken in hand. The Yorkshire unit is similarly engaged on the Huddersfield Sheet, of which a manuscript copy was exhibited in September when the British Association met in Leeds. The map is now engraving and the memoir is being written. Field work in Yorkshire was confined to the Glossop Sheet (86) which is about half finished.

In Northumberland and Durham field work was carried out both in the coalfield in the neighbourhood of Morpeth and in the volcanic rocks of the Cheviot Hills. That field unit has now a considerable area surveyed and not yet ready for publication: consequently field work in the coming season may be considerably reduced.

In Cumberland a notable stage of progress was attained by the completion of two very difficult and important sheets, Whitehaven (28) and Maryport (22) and also of the Brampton Sheet (18) which is principally Carboniferous Limestone with some coal seams. As

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this unit has now finished the very puzzling Whitehaven coalfield, which had not previously been well understood, and as its operations in future will be at some distance from Whitehaven, which is not a very convenient centre, the staff was shifted to London at the end of the year and the Whitehaven office was closed.

In Scotland field work was comparatively small as the slow progress of publication of coalfield maps and memoirs greatly restricted the time available for examining new areas in the field. All the important coalfields of Scotland have now been revised and most of the new six-inch maps are published. Fifeshire and South Ayrshire are the principal districts under investigation at present, with the less important coalfields of Douglas and Muirkirk. Dr. Read made a rapid inspection of parts of Sutherlandshire which had been mapped long ago and now require to be dry-proofed for engraving. Dr. Campbell of Edinburgh University has also furnished a revised one-inch map of the Stonehaven area (Sheet 67), based on a personal examination of all the outcrops. This map is engraving and will soon be published.

In connection with the field work in the various districts the members of the headquarters staff have also displayed great activity. Mr. Pringle, Mr. Chatwin and Dr. Crookall have paid many visits to the field with the object of directing the fossil collectors and securing palaeontological and palaeobotanical specimens and information to complete and illustrate the work of the field geologists. The task of bore examination has been mostly in the hands of Mr. Templeman in England and Mr. Manson in Scotland. Mr. John Rhodes has taken several hundred photographs of typical geological subjects and thirty-four have been taken by Mr. Manson. Mr. Eckford, Mr. Tait and Mr. Strachan have collected specimens for the geologists in Scotland and in Northumberland. The staff of assistants has been increased by the addition of three officers (two Technical Assistants and one General Assistant)—one in Scotland and two in England—and the new recruits have been undergoing training under experienced supervision in the manifold duties they will be called upon to perform.

Publications

The list of publications is exceptionally long and includes the following items :—

English

1 quarter-inch Index, 7 one-inch maps (2 solid and 5 drift), 54 six-inch maps (solid and drift editions of each).

Scottish

4 one-inch maps, 15 six-inch maps (solid and drift editions of each), and 4 Vertical Sections.

Most of these items were in the press at the close of 1926 and the

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work done on them during the year has been principally the correction of engraved proofs and of coloured standards.

Several items in this list are worthy of special mention.

The new quarter-inch Index is the first part of a third edition of the quarter-inch map. The first geological Sheet is in the press and almost ready for issue at the close of the year.

The London District map is in several ways a new departure. It is the largest colour-printed map yet issued by the Geological Survey of Great Britain, measuring 28 in. by 36½ in. and representing an area of 779 square miles. The topographical basis is the excellent one-inch Tourist Map of the Ordnance Survey, which is more thoroughly up-to-date than the maps used in producing our one-inch Sheets of South London (270), North London (256), Beaconsfield (255), Windsor (269), Romford (257), and Dartford (271). The new map contains parts of the six sheets above enumerated but was not printed from their plates as an entirely new series of stones was prepared in order to secure complete uniformity throughout. An interesting feature of this map is the representation of rivers, ponds and reservoirs in blue, as on the ordinary topographical sheets. This gives distinctness to the river-systems and in no way interferes with the usefulness of the map to the geologist. As the London area had previously been represented on four one-inch sheets it is believed that this new map will prove much more convenient to the public and should be especially useful to schools and technical colleges in and around London. Its production was an experiment made to ascertain if the colour-printing process now in vogue for our maps would produce a large and complex sheet in a satisfactory manner, and the general verdict of the public has been that the map is very successful. It is expected that for the use of Londoners interested in geology this will replace all other maps.

Another map that has several new features is the Rochdale map (Sheet 76). Hitherto it has been usual to produce maps of coalfield areas in two editions, 'Solid' and 'Drift.' Where only the 'drift' edition was issued complaints were received that the coalfields were often entirely covered with boulder-clay or gravel and consequently were very inconspicuous. Hence a solid edition was wanted for the use of mining students and mining engineers. In most cases the same engraved plate showing topography and geological lines was used for both editions. In this Rochdale map, however, two engraved geological plates are used. The topographical basis is the same in both, but in the 'solid' plate the drift boundaries are omitted, while in the 'drift' plate many of the outcrops of coal seams and other 'solid' details are not shown. Each map, in fact, is designed for a special purpose. The 'solid' shows all possible detail of the underlying rocks. The 'drift' displays especially the nature and distribution of the superficial deposits. It is believed that in this way a better result is obtained at a trifling extra cost, and the 'drift' map produced is more satisfactory for the geographer and agriculturist, while the mining engineer also obtains

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a map specially adapted for his use. In the difficult matter of map production finality is never reached, but as an experiment the Rochdale Sheet has proved a success and it is probable that future one-inch coalfield maps will follow this model more or less closely. We have in the press a Scottish map (Kilmarnock, Sheet 22) which in some respects is more complete than the Rochdale map; but till the final proofs are passed and copies come from the press it is not possible to pass judgment on it.

The six-inch maps published during the year are exceptionally numerous, and by examining the list it will be seen that many coalfields are receiving attention. These maps are now more nearly reduced to standard form. They usually have measured vertical sections on their margins; and by the thorough use of index letters it is quite possible to represent the whole geology without the use of colour. As a matter of fact students in the universities are now being taught to read these plain or uncoloured maps quite efficiently, and coloured copies are required only for certain special purposes. The sale of plain maps increases yearly, while the sale of hand-coloured copies is continually shrinking.

The six-inch maps of South Wales, revised by Dr. Robertson, are the second editions of maps originally made by Sir Aubrey Strahan and Dr. Gibson, with additional details and corrections to bring them up to date. In Northumberland a new set of topographical six-inch maps has recently been issued by the Ordnance Survey and those sheets in our list which bear the index letter N are on the new topography. The new series does not correspond exactly in numbers or in boundaries with the series which it replaces, and in some cases most of the geology has been transferred from an old series map with little modification, but new indexes and vertical sections are frequently necessary.

Of the four Scottish one-inch maps published during the year two are colour-printed versions of the map originally issued some years ago. The Kirkcudbright map, Sheet 5, has the revision of the Silurian rocks made by Dr. Peach and Dr. Horne; the igneous rocks have been re-named by Dr. Read, and the drift is represented by stipple. The Coll map completes the publication of Mull in colour-printed form.

Both in England and in Scotland a large number of six-inch maps have been prepared in standard form and deposited in the library for reference by the public (pp. 15-16).

The memoirs issued during 1927 were mostly descriptions of new colour-printed one-inch Sheets. The Abergavenny memoir, however, is not accompanied by a new map as that Sheet is neither superseded nor sold out, while the memoir has for some time been out of print, and we have had many enquiries about a new edition. Perhaps the most interesting volume of the year is the third edition of the 'Oil-Shales of the Lothians.' This work is well known as the standard authority on the subject of which it treats. Two new contributors have made their appearance in this edition, Mr. Conacher and Mr.

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E. M. Bailey, both of whom have spent a life time in the Scottish shale-oil industry and are recognized authorities on the subjects they handle in the memoir. This work has been very favourably reviewed by the technical press. The memoir on the South Staffordshire coalfield, by Mr. Whitehead and Mr. Eastwood, fills a recognised gap in our descriptive literature of British coalfields. It follows after 60 years the second edition of the standard work by J. Beete Jukes, which has always been regarded as one of the best and most original monographs on a British coalfield. Unfortunately the coals of this district have been to a large extent worked out, but the history and geological details of the field have received very full attention in the new memoir now published. The Rossendale memoir (Sheet 76) marks the beginning of publication of the revision of the Lancashire coalfield.

The following maps and memoirs were published during 1927 :—

I.—Maps

English and Welsh maps published in 1927

¼ inch to 1 mile:—

Index to Colours and Symbols. *Revised Edition.*

1 inch to 1 mile :—

London District (*Drift Edition*).

Sheet 76.—Rochdale (*Solid and Drift Editions*). By R. L. Sherlock, D. A. Wray, W. Lloyd, L. H. Tonks and W. B. Wright, District Geologist.

Sheet 121.—Wrexham (*Solid and Drift Editions*). By C. B. Wedd, H. H. Thomas, D. A. MacAlister, B. Smith, L. J. Wills and W. B. R. King ; G. W. Lamplugh, District Geologist.

Sheet 139.—Stafford (*Drift Edition*). By E. E. L. Dixon, R. W. Pocock, T. H. Whitehead, T. Robertson and W. Gibson and T. C. Cantrill, District Geologists.

Sheet 207.—Ipswich (*Drift Edition*). By F. J. Bennett, J. H. Blake, W. H. Dalton and W. Whitaker. Transferred to New Series map with minor corrections.

6 inches to 1 mile (coalfield maps) :—

Brecknockshire, 47 N.W. (Mon. 11 N.W.)—Beaufort (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Brecknockshire, 47 N.E. (Mon. 11 N.E.)—Brynmawr (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Brecknockshire, 48 N.W. (Mon. 12 N.W.)—Pwll-du (*Revised Edition*). Original survey by A. Strahan. Revised by T. Robertson.

Cumberland, 18 N.E.—Nether Denton. Original survey by E. J. Hebert. Re-surveyed by F. M. Trotter ; B. Smith, District Geologist.

Cumberland, 19 S.W.—Midgeholme. Original survey by E. J. Hebert. Re-surveyed by F. M. Trotter ; B. Smith, District Geologist.

Cumberland, 25 N.E.—Cold Fell. Original survey by E. J. Hebert. Re-surveyed by F. M. Trotter ; B. Smith, District Geologist.

Cumberland, 53 N.E.—Seaton. Original survey by R. Russell. Revised by T. Eastwood ; B. Smith, District Geologist.

Cumberland, 67 S.E.—Cleator Moor (*Revised Edition*). Original survey by R. Russell. Revised by A. Strahan. Re-surveyed by B. Smith, District Geologist.

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Cumberland, 68 N.W.—Arlecdon. Original survey by R. Russell. Revised by A. Strahan. Re-surveyed by E. E. L. Dixon ; B. Smith, District Geologist.

Durham, 6 N.W.—Whickham. Original survey by H. H. Howell. Revised by W. Anderson and G. A. Burnett ; R. G. Carruthers, District Geologist.

Durham, 6 N.E.—Gateshead. Original survey by H. H. Howell. Revised by W. Anderson ; R. G. Carruthers, District Geologist.

Durham, 6 S.W.—Burnopfield. Original survey by H. H. Howell. Revised by W. Anderson ; R. G. Carruthers, District Geologist.

Durham, 6 S.E.—Kibblesworth. Original survey by H. H. Howell. Revised by W. Anderson ; R. G. Carruthers, District Geologist.

Glamorganshire, 6 S.E. (Mon. 10 S.E.)—Twyn-carno (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Glamorganshire, 12 S.E.—Blaenllwynau (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Glamorganshire, 13 N.W. (Mon. 17 N.W.)—Bedwellty Pits (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Glamorganshire, 13 S.W. (Mon. 17 S.W.)—Cwm-syfiog (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Monmouthshire, 11 S.W.—Tredegar (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Monmouthshire, 11 S.E.—Aberystruth (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Monmouthshire, 12 S.W.—Blaenavon (*Revised Edition*). Original survey by A. Strahan. Revised by T. Robertson.

Monmouthshire, 18 N.W.—Varteg (*Revised Edition*). Original survey by A. Strahan. Revised by T. Robertson.

Monmouthshire, 18 S.W.—Abersychan (*Revised Edition*). Original survey by A. Strahan. Revised by T. Robertson.

[1]Northumberland, 26 S.W.—Eglingham. Original survey by W. Topley, Revised by G. A. Burnett ; R. G. Carruthers, District Geologist.

[1]Northumberland, 32 S.E.—Lesbury. Original survey by W. Topley. Revised by R. G. Carruthers, District Geologist.

[1]Northumberland, 37 N.E.—Callaly. Original survey by W. Topley. Revised by W. Anderson ; R. G. Carruthers, District Geologist.

[1]Northumberland, 38 N.W.—Edlingham. Original survey by W. Topley. Revised by W. Anderson ; R. G. Carruthers, District Geologist.

[1]Northumberland, 45 N.W.—Framlington Gate. Original survey by W. Topley. Revised by A Fowler ; R. G. Carruthers, District Geologist.

[1]Northumberland, 45 S.E.—Weldon. Original survey by W. Topley. Revised by A. Fowler ; R. G. Carruthers, District Geologist.

[1]Northumberland, 47 N.W.—Hauxley. Original survey by W. Topley. Revised by A. Fowler ; R. G. Carruthers, District Geologist.

[1]Northumberland, 47 S.W.—Hadstone Carrs. Original survey by W. Topley. Revised by A. Fowler ; R. G. Carruthers, District Geologist.

[1]Northumberland, 54 N.E.—Linden. Original survey by W. Topley. Revised by J. Maden ; R. G. Carruthers, District Geologist.

[2]Northumberland, N. 6 N.E.—Felkington. Original survey by W. Gunn. Revised by R. G. Carruthers and A. Fowler ; R. G. Carruthers, District Geologist.

[2]Northumberland, N. 6 S.E.—Duddo. Original survey by W. Gunn. Revised by R. G. Carruthers and F. Marsden ; R. G. Carruthers, District Geologist.

[2]Northumberland, N. 50 N.W.—Pauperhaugh. Original survey by W. Topley. Revised by A. Fowler and J. Maden ; R. G. Carruthers, District Geologist.

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[1]Correspond to Topographical Sheets issued by Ordnance Survey 1894-1897.
[2]Correspond to Topographical Sheets on new meridian revised by Ordnance Survey 1912-1922.

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[1]Northumberland, N. 50 S.W.—Wingate. Original survey by W. Topley. Revised by J. Maden ; R. G. Carruthers, District Geologist.

[1]Northumberland, N. 50 S.E.—Viewlaw. Original survey by W. Topley. Revised by J. Maden ; R. G. Carruthers, District Geologist.

Staffordshire, 71 S.W. (Worcs. 4 S.W.)—Stourbridge. Surveyed by T. H. Whitehead ; T. C. Cantrill, District Geologist.

Yorkshire, 216 N.W.—Thornton. Original survey by J. C. Ward, J. Lucas, C. Fox-Strangways and R. Russell. Re-surveyed by J. V. Stephens ; C. N. Bromehead, District Geologist.

Yorkshire, 216 S.W.—Queensbury. Original survey by J. C. Ward, J. Lucas, C. Fox-Strangways and R. Russell. Re-surveyed by J. V. Stephens ; C. N. Bromehead, District Geologist.

Yorkshire, 216 S.E.—North Bierley. Original survey by J. C. Ward, J. Lucas, C. Fox-Strangways and R. Russell. Re-surveyed by J. V. Stephens ; C. N. Bromehead, District Geologist.

Yorkshire, 217 N.W.—Pudsey. Original survey by J. C. Ward, J. Lucas and R. Russell. Re-surveyed by J. V. Stephens ; C. N. Bromehead, District Geologist.

Yorkshire, 217 N.E.—Armley and Bramley. Original survey by J. C. Ward, J. Lucas and R. Russell. Re-surveyed by Wilfrid Edwards ; C. N. Bromehead, District Geologist.

Yorkshire, 217 S.W.—Tong. Original survey by J. C. Ward, J. Lucas and R. Russell. Re-surveyed by J. V. Stephens ; C. N. Bromehead, District Geologist.

Yorkshire, 217 S.E.—Gildersome. Original survey by J. C. Ward, J. Lucas and R. Russell. Re-surveyed by Wilfrid Edwards ; C. N. Bromehead, District Geologist.

Yorkshire, 231 N.E.—Wyke. Original survey by J. C. Ward and R. Russell. Re-surveyed by Wilfrid Edwards ; C. N. Bromehead, District Geologist.

Yorkshire, 232 N.W.—Birkenshaw. Original survey by R. Russell. Re-surveyed by Wilfrid Edwards ; C. N. Bromehead, District Geologist.

Yorkshire, 232 N.E.—Morley. Original survey by R. Russell. Re-surveyed by Wilfrid Edwards ; C. N. Bromehead, District Geologist.

Yorkshire, 232 S.W.—Liversedge. Original survey by R. Russell. Re-surveyed by C. N. Bromehead, District Geologist.

Yorkshire, 232 S.E.—Batley. Original survey by R. Russell. Re-surveyed by Wilfrid Edwards ; C. N. Bromehead, District Geologist.

Yorkshire, 245 N.E.—Barkisland. Original survey by J. R. Dakyns. Re-surveyed by D. A. Wray ; C. N. Bromehead, District Geologist.

Yorkshire, 246 N.W.—Elland. Original survey by J. R. Dakyns, J. C. Ward and R. Russell. Re-surveyed by D. A. Wray ; C. N. Bromehead, District Geologist.

Yorkshire, 246 N.E.—Rastrick. Original survey by J. C. Ward and R. Russell. Re-surveyed by C. N. Bromehead, District Geologist.

Yorkshire, 246 S.W.—Golcar. Original survey by J. R. Dakyns, J. C. Ward and R. Russell. Re-surveyed by D. A. Wray ; C. N. Bromehead, District Geologist.

Yorkshire, 247 S.W.—Kirkheaton. Original survey by A. H. Green, J. C. Ward and R. Russell. Re-surveyed by D. A. Wray ; C. N. Bromehead, District Geologist.

Scottish maps published in 1927

1 inch to 1 mile :—

Sheet 5.—Kirkcudbright. Revised by B. N. Peach and J. Horne.

[1]Correspond to Topographical Sheets on new meridian revised by Ordnance Survey 1912-1922.

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Mining information by G. V. Wilson. (*Colour-printed edition, replacing hand-coloured edition*).

Sheet 19.—Bowmore. By S. B. Wilkinson and B. N. Peach. (*Colour-printed edition, replacing hand-coloured edition*).

Sheet 27.—Portaskaig. By B. N. Peach, S. B. Wilkinson and C. T. Clough. (*Colour-printed edition, replacing hand-coloured edition*).

Sheet 51.—Coll. By E. B. Bailey, J. E. Richey, G. V. Wilson, G. A. Burnett, V. A. Eyles and J. B. Simpson; E. B. Bailey, District Geologist.

6 inches to 1 mile (coalfield maps) :—

Ayrshire, 24 S.E.—Weitshaw Muir. Original survey by J. Geikie. Revised by A. G. MacGregor; E. B. Bailey, District Geologist.

Ayrshire, 26 S. W.—Ponesk Burn. Original survey by B. N. Peach. Revised by G. V. Wilson; M. Macgregor, District Geologist.

Ayrshire, 29 N.E.—Sorn, North of. Original survey by J. Geikie. Revised by J. B. Simpson; E. B. Bailey, District Geologist.

Ayrshire, 29 S.E.—Darnconner. Original survey by J. Geikie. Revised by J. B. Simpson; E. B. Bailey, District Geologist.

Ayrshire, 30 S. W.—Aird's Moss. Original survey by B. N. Peach. Revised by E. M. Anderson and J. B. Simpson; E. B. Bailey and J. E. Richey, District Geologists.

Ayrshire, 35 S.E.—Glaisnock. Original survey by J. Geikie. Revised by J. B. Simpson; E. B. Bailey, District Geologist.

Ayrshire, 40 N.E.—Polquhairn. Original survey by J. Geikie. Revised by J. B. Simpson; E. B. Bailey, District Geologist.

Ayrshire, 41 S.W.—Craigman. Original survey by J. Geikie and B. N. Peach. Revised by J. B. Simpson; E. B. Bailey, District Geologist.

Fifeshire, 39 N.E.—Fordell. Original survey by A. Geikie. Revised by J. K. Allan; C. H. Dinham, District Geologist.

Lanarkshire, 16 S.E.—Jackton. Original survey by J. Geikie. Revised by R. G. Carruthers, C. H. Dinham and J. E. Richey; L. W. Hinxman and E. B. Bailey, District Geologists.

Lanarkshire, 31 S.E.—Auchlochan. Original survey by B. N. Peach. Revised by L. W. Hinxman and G. Ross; M. Macgregor, District Geologist.

Lanarkshire, 37 N. E.—Coalburn. Original survey by B. N. Peach. Revised by C. B. Crampton and G. Ross; M. Macgregor, District Geologist.

Stirlingshire, 17 N.E.—Stirling, St. Ninians. Original survey by B. N. Peach. Revised by C. H. Dinham and H. H. Read; C. H. Dinham, District Geologist.

Stirlingshire, 18 N.W.—Fallin. Original survey by B. N. Peach. Revised by C. H. Dinham and H. H. Read; C. H. Dinham, District Geologist.

Stirlingshire, 23 N.E.—West Plean. Original survey by B. N. Peach. Revised by C. B. Crampton and C. H. Dinham; L. W. Hinxman and C. H. Dinham, District Geologists.

Manuscript copies of the following maps on the scale of six inches to one mile were deposited in the Library for public reference. These maps are not to be published. The English maps are deposited in the head office in London. The Scottish maps are deposited in the Edinburgh office.

English manuscript maps deposited for reference

Berkshire, 49 N.E. (Hants. 12 N.E.) (part); 50 N.W. (Hants. 13 N.W.) (part).
Cumberland, 54 S.E.

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Essex, 6 S.W. (Suffolk 72 S.W.) (part), S.E. (Suffolk 72 S.E.); 12 N.W. (Suffolk 79 N.W.), N.E. (Suffolk 79 N.E.).
Hampshire, 12 S.E. (part); 13 S.W.; 20 N.E. (part); 21 N.W. (part).
Shropshire, 16 S.E.; 23 N.E. (and 24 N.W.), 23 S.E.; 30 N.E., S.E.; 31 N.W., S.W.
Staffordshire, 22 S.W., S.E.; 23 S.W., S.E.; 24 S.W., S.E.; 25 S.W. (part); 28 N.W., N.E., S.E.; 29 N.W., N.E., S.W., S.E.; 30 N.W., N.E., S.W., S.E.; 31 N.W. (part), S.W. (part); 35 N.E., S.E.; 36 N.W., N.E., S.W., S.E.; 37 N.W., N.E., S.W., S.E.; 38 N.W. (part), S.W. (part); 43 N.W., N.E., S.W., S.E.; 44 N.W., N.E., S.W., S.E.
Surrey, 15 (N.W. and N.E.), S.E.; 16 N.W., N.E., S.W., S.E.; 17 S.W., S.E.; 18 S.W. (part); 22 N.E., S.W., S.E.; 23 N.W., N.E., S.W., S.E.; 24 N.W., N.E., S.W., S.E.; 25 N.W.; 30 N.W., N.E., S.W., S.E.; 31 N.W., N.E., S.W., S.E.; 32 N.W., N.E., S.W., S.E.; 37 N.W. (part), N.E. (part); 38 N.W. (part), N.E. (part); 39 N.W. (part), N.E. (part).
Sussex, 2 S.W., S.E.; 10 N.W., S.W.; 12 N.W. (part), N.E. (part); 13 N.W. (part), N.E. (part); 20 N.E., S.E.; 21 N.W., S.W., S.E.; 22 S.W. (part), S.E. (part); 23 S.W. (part), S.E.; 33 N.E., S.E.; 34 N.W., N.E., S.W., S.E.; 35 N.W., N.E., S.W., S.E.; 36 N.W., N.E., S.W., S.E.; 47 N.W., N.E., S.E., ; 48 N.W., N.E., S.W., S.E.; 49 N.W., N.E., S.W., S.E.; 60 N.E., S.E.; 61 N.W., N.E., S.W., S.E.; 62 N.W., N.E., S.W., S.E.; 63 N.W., N.E., S.W., S.E.; 68 N.W. (part), S.W. (part), S.E. (part); 72 N.W., N.E., S.E.; 73 N.W., N.E., S.W., S.E.; 78 N.W., N.E., S.E.; 79 N.W., N.E., S.W., S.E.; 80 N.W., N.E., S.W.; 81 N.W., N.E.; 82 N.E.; 83 N.W.
Worcestershire, 39 S.E. (part); 46 N.E. (part).
Yorkshire, 259 N.E.; 260 N.W.

Scottish manuscript maps deposited for reference

Argyllshire, 51; 63 (and 64); 65 (and 79); 70 S.W., S.E.; 78; 95; 97; 104 N.W., N.E., S.E.; 109 N.W., S.E.; 116.
Ayrshire, 19 N.E., S.E.; 32 S.E.; 33 S.W.; 39 N.E.; 51 S.E.; 52 S.W., S.E.; 53 N.W.; 57 N.E.; 58 N.W.
Berwickshire, 13; 19.
Caithness-shire, 26a N.E., S.E.; 31a N.E., S.E.
Edinburghshire, 20 N.W., S.W.; 23; 25.
Haddingtonshire, 22 N.W., S.W.
Lanarkshire, 22 N.E., S.E.; 26 S.E.; 29 N.E., S.E.; 31 N.W., S.W.; 37 N.W.
Roxburghshire, 1 S.W., S.E.; 2 S.W.; 3; 4 N.W., S.W.; 7 N.E., S.E.; 8; 13 N.E., S.W., S.E.; 14; 18 N.E., S.E.; 19; 20.
Selkirkshire, 1 S.W.; 3; 4 S.W.; 7.
Sutherland, 33; 34; 35; 42; 43; 44; 52; 53; 54; 62; 63; 64; 75.

List of maps in the press at the close of 1927

English maps in the press

½ inch to 1 mile:—

Sheet 11.—Derby, Lincoln, Sheffield, Stafford (*Solid Edition*). *Reprinting.*

1 inch to 1 mile:—

Sheet 77.—Huddersfield (*Drift Edition*).
Sheet 137.—Oswestry (*Solid and Drift Editions*).
Sheet 153.—Wolverhampton (*Solid and Drift Editions*).
Sheet 206.—Sudbury (*Drift Edition*).
Sheet 208.—Woodbridge (*Drift Edition*).
Sheet 225.—Felixstowe (*Drift Edition*).
Sheet 274.—Ramsgate (*Drift Edition*).

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Sheet 285.—Aldershot (*Drift Edition*).
Sheet 290.—Dover (*Drift Edition*).
Sheet 320.—Hastings (*Drift Edition*).
Sheet 321.—Dungeness (*Drift Edition*).

6 Inches to 1 mile (coalfield maps) :—

Cumberland, 19 N.W. ; 53 N.E. ; 54 N.W., S.W. ; 62 N.W., S.W. ; 72 N.E.
Glamorganshire (*Revised Edition*), 12 N.E. (Mon. 16 N.E.).
Lancashire, 87 N.W., N.E., S.W. ; 88 N.W., N.E., S.E. ; 95 N.W.
Monmouthshire (*Revised Editions*), 17 N.E., S.E. ; 18 S.E.
Northumberland, N. 10 N.E. ; N. 11 N.W. ; N. 35 S.E. ; N. 43 N.W., S.E. ; N. 49 S.E.
Shropshire, 12 N.W., N.E., S.W., S.E. ; 18 N.E. ; 19 N.W., S.W.
Yorkshire, 215 N.E., S.E. ; 246 S.E. ; 247 N.W., N.E. ; 260 N.E. ; 261 N.W.

Scottish maps in the press

1 inch to 1 mile :—
Sheet 22.—Kilmarnock (*Solid and Drift Editions*).
Sheet 23.—Hamilton (*Solid Edition*).
Sheet 32.—Edinburgh (*Drift Edition*).
Sheet 67.—Stonehaven.

6 inches to 1 mile (coalfield maps) :—

Ayrshire, 26 S.E. ; 30 N.E. ; 31 N.W. ; 34 S.W. ; 40 N.W., S.W., S.E. ; 41 N.W. ; 46 N.W., N.E., S.E. ; 47 N.W. ; 50 N.E., S.E.
Clackmannanshire, 139 N.W., S.E.
Fifeshire, 34 S.E. ; 37 N.W. ; 40 N.E. (and 41 N.W.)
Fifeshire and Kinross-shire, 34 N.E.
Lanarkshire, 19 N.W. ; 32 S.W., S.E.
Stirlingshire, 10 S.E. ; 18 S.W., S.E.

II.—Vertical Sections of Strata

In addition to the maps enumerated above four large sheets of vertical sections of the strata of the Central Coalfield of Scotland, mostly drawn from details of borings and shafts, on the scale of one inch to 40 feet, have been published. These serve to illustrate the series of Economic Memoirs on the Central Coalfield of Scotland and the six-inch published maps of that coalfield. Each sheet contains from ten to twenty vertical sections. Another sheet illustrating this coalfield is in the press and four sheets of vertical sections illustrating the South Wales Coalfield are being reprinted.

Scottish Vertical Sections published in 1927

Sheet 10.—Vertical Sections illustrating the Central Coalfield. Coal Measures in Areas IX, VI, and south part of VII. Hamilton, Dalserf, Wishaw, Shotts, Fauldhouse, and Armadale Districts.
Sheet 12.—Vertical Sections illustrating the Central Coalfield. Coal Measures showing strata below Splint Coal in Area VII. Rutherglen, Motherwell, and Holytown Districts.
Sheet 13.—Vertical Sections illustrating the Central Coalfield. Millstone Grit and Upper Limestone Group, along south and east borders. Areas IV, IX, VI and II.

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Sheet 15.—Vertical Sections illustrating the Central Coalfield. Limestone Coal Group, Lower Limestone Group and part of Calciferous Sandstone Series, along south and east borders. Areas IX, VI and II.

English Vertical Sections in the press at the close of 1927

Sheet 81.—Sections of Shafts in the Steam Coal Series in the 1-inch map Sheet 232 (parts of Monmouthshire and Glamorganshire). Scale 100 feet to an inch. *Reprinting.*

Sheet 83.—Sections of Shafts in and below the Pennant Grit in the Taff, Aberdare and Rhondda Fach Valleys. Scale 100 feet to an inch. *Reprinting.*

Sheet 84.—Sections of Shafts below the Pennant Grit in the Rhondda Fawr and in the Upper Measures at Llantwit. Scale 100 feet to an inch. *Reprinting.*

Sheet 85.—Sections of Shafts, &c., in the Tawe, Dulais, Neath, Avan, Llynfi, Garw and Ogmore Valleys. Scale 100 feet to an inch. *Reprinting.*

Scottish Vertical Sections in the press at the close of 1927

Sheet 14.—Vertical Sections illustrating the Central Coalfield. Limestone Coal Group, Lower Limestone Group and part of Calciferous Sandstone Series in Areas IV and VIII. Paisley, Giffnock, and East Kilbride.

III.—Memoirs

The following list shows the memoirs published during the year 1927. The work done on them has been mainly the correction of proofs and preparation of indexes.

English Memoirs published in 1927

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for the Year 1926. 202 pp.; 6 plates; 42 text-figures. 1927. Price 4*s.* 6*d. net.*

Special Reports on the Mineral Resources of Great Britain: Vol. X. Iron Ores—The Haematites of the Forest of Dean and South Wales. By T. Franklin Sibly, D.Sc. *Second Edition.* Revised by W. Lloyd, B.Sc. 101 pp.; 17 text-figures. 1927. Price 2*s. net.*

The Geology of the Southern Part of the South Staffordshire Coalfield (South of the Bentley Faults). By Talbot H. Whitehead, M.Sc., A.R.C.Sc., and T. Eastwood, A.R.C.Sc. With contributions by T. Robertson, B.Sc., Ph.D., A.Inst.M.M. 218 pp.; 13 plates; 5 text-figures. 1927. Price 6*s.* 6*d. net.*

The Geology of the South Wales Coalfield. Part II. Abergavenny. (Explanation of one-inch Sheet 232: England and Wales). By Aubrey Strahan, M.A., F.G.S., and Walcot Gibson, F.G.S. With notes by J. R. Dakyns, M.A., and Prof. W. W. Watts, M.A. *Second Edition* by T. Robertson, B.Sc., Ph.D., A.Inst.M.M. 145 pp.; 4 plates; 20 text-figures. 1927. Price 3*s.* 6*d. net.*

The Geology of Belford, Holy Island, and the Farne Islands. (Explanation of one-inch Sheet 4: England and Wales). By W. Gunn. *Second Edition* by R. G. Carruthers, C. H. Dinham, B.A., G. A. Burnett, B.Sc., and J. Maden, M.Sc. 195 pp.; 3 plates; 2 text-figures. 1927. Price 4*s. net.*

The Geology of the Rossendale Anticline. (Explanation of one-inch Sheet 76 (Rochdale): England). By W. B. Wright, M.I.M.E., R. L. Sherlock,

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D.Sc., A.R.C.Sc., D.A. Wray, M.Sc., W. Lloyd, B.Sc. and L. H. Tonks, M.Sc. 182 pp.; 7 plates; 38 text-figures. 1927. Price 4*s.* 6*d. net.*

The Geology of the Country around Wrexham. (Explanation of one-inch Sheet 121: England and Wales). Part I. Lower Palaeozoic and Lower Carboniferous Rocks. By C.B. Wedd, B.A., B. Smith, M.A., Sc.D., and L. J. Wills, M.A., Ph. D. With a contribution by G. W. Lamplugh, F.R.S. 179 pp.; 4 plates; 14 text-figures. 1927. Price 4*s.* 6*d. net.*

The Country between Stafford and Market Drayton. (Explanation of one inch Sheet 139: England and Wales). By T. H. Whitehead, M.Sc., A.R.C.Sc., E. E. L. Dixon, B.Sc., A.R.C.Sc., R. W. Pocock, M.Sc., T. Robertson, B.Sc., Ph.D., and T. C. Cantrill, B.Sc. 128 pp.; 5 plates; 5 text-figures. 1927. Price 3*s.* 6*d. net.*

The Geology of the Country around Ipswich. (Explanation of one-inch Sheet 207: England). By P. G. H. Boswell, D.Sc., Professor of Geology in the University of Liverpool. 121 pp.; 4 plates; 25 text-figures. 1927. Price 3*s.* 6*d. net.*

Scottish Memoirs published in 1927

Summary of Progress—*see* p. 18.

The Oil-Shales of the Lothians. *Third Edition.* Part I. The Geology of the Oil-Shale Fields. By R. G. Carruthers. Based on the work of H. M. Cadell and J. S. Grant Wilson. Part II. Methods of working the Oil-Shales. By W. Caldwell. Part III. Chemistry and Technology of the Oil-Shales. By E. M. Bailey. Part IV. History of the Scottish Oil-Shale Industry. By H. R. J. Conacher. 274 pp.; 12 plates; 75 text-figures. 1927. Price 5*s.* 6*d. net.*

English Memoirs in the press at the close of 1927

Palaeontology. Vol. I. Part 5. Plectambonites and some Allied Genera.

Palaeontology. Vol. III. Part I. The British Carboniferous Producti. II.—Productus (*sensu stricto*); Semireticulatus and Longispinus Groups

Wells and Springs of Somerset.

Wells and Springs of Warwickshire.

The Geology of the Country around Wrexham. (Explanation of one-inch Sheet 121: England and Wales). Part II. Coal Measures and Newer Formations.

The Geology of the Country around Woodbridge, Felixstowe, and Orford. (Explanation of one-inch Sheets 208 and 225: England).

The Geology of the Country near Hastings and Dungeness. (Explanation of one-inch Sheets 320 and 321: England).

Scottish Memoirs in the press at the close of 1927

The Geology of Arran.

Special Reports on Mineral Resources

A second edition of Dr. Sibly's memoir on the Iron Ores of the Forest of Dean and South Wales, revised thoroughly after a careful examination of both districts by Mr. W. Lloyd, was the only volume of this series that made its appearance during 1927. Visits have been paid by the field geologists to several lead, zinc and copper mines when active developments were in progress, but until the current editions of these memoirs are sold out it is not necessary to replace them, as the new information which is being received is

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not sufficiently important to warrant that step. Mr. Dines, who is a trained mining engineer, has been engaged for some time in revising the mining notes and mineral lodes on our set of mines maps of Cornwall and Devon so as to make sure that new information is correctly recorded as it is received. The oil-shales memoir previously mentioned might almost be regarded as a volume of this series, and it may be noted that the map illustrating that memoir has been very carefully brought up to date by incorporating all the details received during the last ten years from the engineers of Scottish Oils, Ltd., who have been most willing to help. The manuscript of a Special Report on Ball Clays has been written by Dr. A. Scott of the Pottery Laboratory, Stoke-upon-Trent.

Water Supply Memoirs

No memoir on water-supply has been published during the year. This is principally due to the pressure of other work. On the other hand, a very large amount of manuscript was being prepared for press during the latter part of the year as will be seen from the fact that the following memoirs are in hand :—

Wells and Springs of Somerset (in page proof)
Wells and Springs of Warwick (in galley proof)
Wells and Springs of Sussex (printing)
Wells and Springs of Derby (in preparation)
Wells and Springs of Worcestershire (manuscript under revision).

The following memoirs of this series are also in hand but are not yet in an advanced state :—

London Wells (second edition)
Wells and Springs of Gloucester (manuscript under revision).

This series of publications appeals only to a limited public but has a steady sale, as witness the fact that the Sussex memoir has now sold out, and the Supplement to that memoir is also in demand and a new volume on the county containing many important sections recently obtained and not previously published is now in the press. In the memoirs enumerated above great care is taken that both the records of the wells and their exact situation are thoroughly checked as otherwise the information given loses a great part of its value.

The enquiries regarding water supplies from deep wells received from borers and engineers continue to be very numerous, and in turn we receive from the principal firms engaged in this work very full information about new wells. No opportunity is lost of making additions to the large collection of well records in the possession of the Survey. This constitutes a mass of information of the highest possible value for health, town-planning and industry, and though much of it is now published and available in printed form a very large amount is contained in our manuscript records, which, under the necessary precautions, are generally available, wholly or in part, to engineers and others who wish to make use of them. These records are frequently consulted by public departments. Apart

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altogether from their practical value as indications of water resources still available, they are of great use to the geologist as supplying particulars of the underground strata in the districts where they belong.

Inspection of Bores and Shafts

In last year's *Summary of Progress* (p.25) it was announced that under the Mining Industry Act, 1926, powers had been given to the Geological Survey of Great Britain to examine all mining plans of working mines and receive compulsory notification of borings and shaft-sinkings intended to reach a depth of 100 feet or more.

By the willing co-operation of the Mining Industry we are now in receipt of notification of all important borings for minerals and it has been arranged that one or more officers of the Survey will visit all bores that are of any significance, will check the records and take such specimens of rocks and fossils as are necessary.

Two experienced technical assistants, Mr. Templeman (in England) and Mr. Manson (in Scotland), have been allocated entirely to this work. They obtain the records, check them, and deposit them in our registered collections. If the borings show new points of geological interest they are also visited occasionally by the geologists who are specially concerned with the district. The number of specimens of rocks and fossils obtained in this way is gradually increasing, and the value and reliability of the bore records for geological purposes is very much enhanced. Often the borer or mining engineer is concerned only with one bed, say a coal seam or a bed of iron ore. To him the other rocks may appear meaningless; but to a geologist the whole core is significant and many details are of interest that would escape the attention of the severely practical observer. It is found, however, that the borers and engineers are often much interested in the geological interpretation of the bores and welcome the visits of geologists who are prepared to discuss the general inferences that arise from the work.

The number of bore notifications received up to 31st December, 1927 was, England 38, Scotland 70, and a large number of visits was paid to them both by the geologists and the technical assistants. It is believed that no really important information has been lost and that much has been learned that might otherwise have escaped our attention. The mining industry has not been in a very prosperous state during the year under review and it is probable that with a return of prosperity the amount of boring and shaft-sinking will increase considerably.

Hitherto access to plans of mines and records of bores has been possible only with the permission of the engineers or proprietors of the workings. It is gratifying to be able to state that very seldom has permission been refused and then only for very serious reasons such as business negotiations or impending litigation. The Survey is now in a more secure position, though in actual practice this does not matter very much. The principal gain is that all mineral bores

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are notified and all working plans are open to examination. Consequently much time will now be saved that was formerly occupied in correspondence, requests for permission, and so on. The condition of absolute secrecy imposed on Survey officers, except where sanction has been obtained for publication, remains as stringent as before; but this has seldom proved a very serious impediment except where the best possible reasons could be adduced in favour of it.

Soil Mapping

Further progress has been made in co-operative work between our field geologists and the soil experts under the aegis of the Development Commission, the Ministry of Agriculture and Fisheries, England, and the Board of Agriculture, Scotland. A system of notation for variations of soil texture suitable for adoption on our six-inch field maps is still under consideration; the present method might undoubtedly be made more complete and comprehensive. Photographic copies of six-inch maps of certain districts have been supplied to some of the agricultural officers and a considerable development of this kind of co-operation seems possible in the future. In September a joint meeting of soil-experts and field geologists was held near Scarborough, with the object of working out some practical problems together under the best possible conditions. The Survey was represented at this conference by Messrs. Eastwood, Wray, and Simpson. The results were of great interest and seem to show that in some areas at any rate the Geological Survey's drift maps might be of considerable value to soil mappers. These maps are in no sense agricultural or soil maps, but in the hands of an agriculturalist who understands them they have considerable value as indications of the varieties of soil likely to be met with and their probable distribution and origin.

A very interesting piece of work has been done in the Kilmarnock area where Professor Berry and his assistants have taken in hand the survey of a district corresponding to one-inch geological Sheet 22 and have prepared a map showing soils classified according to their textures. Our new geological sheet is being engraved for publication and advance copies of the 'drift' edition were supplied to the soil workers. A comparison of the two sets of maps shows many interesting points of similarity and not a few striking differences. It is too soon as yet to attempt to formulate any conclusions, but the work is distinctly of great promise. The form of publication which will be adopted is not yet decided but Professor Berry has promised to contribute a chapter on 'soils' to the memoir on that district which is now in preparation, and this will be the first contribution to this subject that the Survey has issued for many years.

The Geological Survey has also continued to give assistance to the officers of Agricultural Colleges who desire to obtain more complete geological drift maps of areas in which they were making special researches. Dr. Ogg's work in East Lothian is being followed

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with great interest and all help that the staff in Edinburgh can give to the agricultural soil investigators is being freely accorded.

Geophysical Surveying

Much attention has been directed of recent years to the use of geophysical methods for geological surveying. As a rule the object aimed at has been the detection of deposits of economic minerals such as oil, iron ores, salt and lead ores. The methods employed are very numerous, being gravitational, electrical, magnetic, seismic, acoustic, and by means of wireless rays. Each of these methods has its special applications and is suitable for the attack of problems of a definite kind and they are sometimes used in conjunction as one of them may supplement the information gained in other ways. It may be stated that as a general rule these new devices are in the hands of commercial companies and exploratory syndicates and the results obtained are very frequently not published or available to other scientific workers. Special schools have been established at some Continental universities for training and instruction in these operations and a considerable literature exists, though mostly restricted to the scientific groundwork on which the practical processes are founded. The value of these methods has been abundantly proved in many instances, but in others the geophysical surveys require still to be supplemented and definitely tested by boring, mining or excavation. They have certainly awakened widespread interest among economic geologists and strong expectations have been aroused that they will ultimately prove of the greatest practical value. As yet few official or national Geological Surveys have done much work of this kind, but in Russia, Sweden and Spain they have been employed by the state surveys and reports of the results have been published. In each of these cases it has been found that in skilled hands and under adequate supervision these geophysical surveys are of considerable utility in locating deep-seated structures and mineral deposits. Our attention was specially directed to these means of exploration by Sir John Cadman, a member of the Geological Survey Board, and by his kindness and that of the Directors of the Anglo-Persian Oil Company Dr. McLintock and Mr. Phemister were allowed to visit Persia and join the Company's geophysical survey parties in the field. A report of the operations was contained in last year's *Summary of Progress* and the impression produced was so favourable that it was decided as soon as possible to undertake researches of this nature in Great Britain. We are also greatly indebted to the kindness of Mr. E. Lancaster-Jones and Captain H. Shaw, officers of the Science Museum, South Kensington, who had had considerable experience of this class of work and have proved very helpful in many ways.

Means were found early in 1927 to purchase an Eötvös balance of the type made in London by Messrs. Oertling and constructed under the supervision of Captain Shaw and Mr. Lancaster-Jones. This was supplied early in May and Dr. McLintock and Mr. Phemister

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proceeded at once to test and calibrate the instrument in the crypt of the Geological Museum and to practise the manipulations before proceeding to the field. It may be said that the instrument has proved very satisfactory and has worked well in every respect.

A field party was then got together consisting of the two geologists above named with two technical assistants and a labourer. Surveying instruments for the necessary surface surveys were purchased, as well as tents, transport and all necessaries for a field unit of five or six men.

The problem investigated was not the usual one of finding new deposits or concealed structures by means of this instrument. On the contrary it was decided to apply the instrument to the examination of certain districts where it was known that geological structures or subjacent rock masses were present that should produce a notable effect on the balance. In this way it was hoped to ascertain the exact field in which its employment was justified, and if possible the limitations of the method. Although qualitative results were all that was expected in the earlier experiments it was considered possible that in favourable circumstances quantitative accuracy might also be approached. The direct object in view, however, was to learn thoroughly the methods of surveying and to put the balance to the test over known structures before proceeding to the examination of geological problems which were as yet partly or wholly unsolved.

Our first object, accordingly, was to find a suitable problem, and after considering a number of structures and making a careful preliminary inspection of the ground it was decided to begin with a survey of the underground extension of the well-known Swynnerton dyke in Staffordshire, where its course is buried beneath drift and possibly also Triassic Marls. For this purpose a situation was selected that was not too inaccessible, and where the ground surface was reasonably level and free from major irregularities that would need careful survey and elaborate calculation before the geophysical results could be reduced to final form.

The field work was begun in July, and though the weather was very wet eighteen stations were finished in a little less than a month. The preliminary results were calculated in the field and subsequently thoroughly revised after the return to headquarters. No difficulties were experienced with the balance, which worked well throughout, but for greater accuracy observations were made only after sunset and the photographic method of registration was not employed. All observations were made visually and repeated till constant readings were obtained.

The results were in every way satisfactory and a preliminary account of them was published in the *Mining Magazine* for January, 1928. For further details the reader is referred to the Appendix I, (Part II). We are indebted to the editor of the *Mining Magazine* for the loan of the *cliches* from which the illustrations are printed. These operations showed that the balance is a perfectly practical

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instrument, and though the manipulations and calculations are certainly delicate and complex a field unit can be trained to do geophysical work with this instrument in a comparatively short time.

After the completion of this campaign the instruments were brought back to London and overhauled and adjusted. It was then decided to select a new problem for investigation that presented more difficulties than the previous one. For this purpose it seemed likely that a buried channel filled with drift, clay and gravel, would prove satisfactory. This has, of course, well-defined practical bearings, as in coalfields where shallow seams are being worked channels such as these require to be located if possible before they are encountered in mining operations.

To the north-west of Glasgow the River Kelvin in pre-Glacial times flowed in a deep valley which is now entirely filled with Glacial deposits. The present surface is nearly a flat plain, but borings put down in search of minerals have shown that the old channel is about a mile broad and not less than 300 ft. deep in its deepest portion. Moreover, it was known from the records of these borings that a hummock of rock rises from the floor of the channel and reaches within 70 ft. of the surface, though nowhere exposed to view. On each side of this hummock there is a deep drift-filled valley. As the surface conditions were comparatively favourable and as the main elements of the problem were already known through the bore records, this seemed in every way a good opportunity for putting the balance to a further test. The difference between the specific gravity of the Carboniferous sandstones and shales forming the banks of the channel and the rocky protuberance and the specific gravity of the sands and gravels (probably water-logged) that occupy the channel seemed likely to be sufficient to yield measurable results.

The instruments were transferred in November, and a camp established at Drumchapel, eight miles north-west of Glasgow. The personnel of the unit was mostly the same as that which had been at work in Staffordshire though some of the English technical assistants were replaced by Scottish. The weather at first was favourable and at an early stage it was clear that the geophysical survey was going to provide evidence of a perfectly definite order. The buried rocky knoll was soon located and by the close of the year about one third of its circumference had been mapped out. It proved to have, however, a considerably different shape from that provisionally deduced from the scanty records obtained in the borings. Its configuration is that of a mass elongated in a north-west and south-east direction with steep sides. Before the end of the year its north-west limits had not yet been defined. Some idea has also been obtained in a preliminary way of the relative steepness of the slopes that bound the rock knoll and adjacent faces of the buried channel. The investigation is going to be carried on as long as the results obtained seem worth the trouble and time expended, but it is not at present possible to give more than a very incom-

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plete account of them. Undoubtedly in such questions as these the evidence of surveys with the Eötvös balance may be very useful. The work is difficult, slow and costly, but the only other means of proving the ground would have been by borings and the geophysical survey is much more complete and gives a far better general solution, though perhaps less strictly accurate in detail, than a number of deep bores.

No attempt has yet been made to try the other kinds of geophysical work that are now being employed for geological purposes; it is possible, however, that after the Eötvös balance has been tested on a variety of geological structures some of the electrical, magnetic and other devices may be similarly experimented with. It may be noted that the Australian Research Council has instituted a programme of geophysical exploration in Australia. The Department of Scientific and Industrial Research is interested in this and has undertaken to give all possible assistance. A committee was appointed to consider programmes and of this committee Dr. McLintock was a member[1]. The Australian Research Council has sent one of its officers, Mr. Lewis, to study the use of the Eötvös balance under Dr. McLintock and he has put in a period of preliminary work in the Geological Museum and a period of field work at Drumchapel which will render him familiar with the operations necessary for conducting surveys of this class.

New Scottish Headquarters

For the past 22 years the Geological Survey has had its Edinburgh office at 33 George Square, in a large house that was at one time occupied by the famous artist Sir Noel Paton. As two large studios and a corridor had been erected in the garden excellent accommodation was provided for the palaeontological collections with abundant light for working purposes, and both in situation and in capacity that house was excellent. The property, however, was acquired by the University of Edinburgh, who have now decided to convert it into hostels for students. New offices consequently had to be obtained and after considerable search H.M. Office of Works decided to purchase a roomy villa on the south side of Edinburgh rather more than a mile from the previous headquarters. This has the disadvantage of greater distance from the Royal Scottish Museum where our exhibited collections are displayed in a special gallery; on the other hand, it is nearer the University geological department which is now at the King's Buildings, about half a mile from Southpark, the new office of the Geological Survey. At the close of the year workmen were busy installing central heating, electric light, telephones, etc., and it is expected that the transfer to new quarters will take place in April or May, 1928.

[1] Geophysical Surveying. Report of a Sub-Committee of the Committee of Civil Research. (Empire Marketing Board), Nov. 1927, pp. 1-21.

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Staff Changes

Mr. T. C. Cantrill, District Geologist, has taken his retirement, and Mr. C. H. Dinham will now superintend Mr. Cantrill's unit. Owing to his long experience in South Wales, North Wales and the Midlands, Mr. Cantrill's services were highly valued and his extensive knowledge was backed by sound judgment and great diligence. The Survey has lost one geologist, Mr. Maden, by death as the result of an accident. Two others have been incapacitated for a considerable time by illness. No addition has been made to the list of geologists during the year, but the establishment of technical assistants has been increased by two and that of the general assistants by one.

Mention should also be made of the death of Mr. J. B. Hill which took place in London on 18th December, 1927. Mr. Hill had served in Argyllshire, Cornwall, South Wales and other districts and his best known contributions to Survey literature are *The Geology of Mid-Argyll* (1905), *The Geology of the Sea-board of Mid-Argyll* (1909), *The Geology of Falmouth and Truro and of the Mining District of Camborne and Redruth* (1906), and *The Geology of the Lizard and Meneage* (1912). He was transferred from the Geological Survey of Great Britain to the Ministry of Health in 1911 and served as geological adviser for 11 years. Mr. Hill had all the qualities which make a successful field geologist, good health, great powers of observation, steady industry and intense interest in the subject. His colleagues always regarded him as a most valuable member of the staff in addition to being a pleasant companion and a shrewd judge of men.

Collaboration

The Survey has received professional assistance from numerous British geologists and palaeontologists during the past year and grateful acknowledgment must be made of their services. Dr. Sibly revised the proofs of the memoir on the Iron Ores of the Forest of Dean and Professor Boswell performed similar duties for his memoir on Ipswich. Messrs. Caldwell, Bailey and Conacher have passed the proofs of their contributions to the memoir on the 'Oil Shales of the Lothians.' Dr. Tyrrell has completed his manuscript of a memoir on the geology of Arran. Two palaeontological memoirs are in the press, one by Miss Muir-Wood and another by Professor O. T. Jones, and the authors have revised the proofs which are now nearly ready for publication. Mr. Osborne White has completed an account of the geology of the district around Ramsgate and Dover, and this memoir has not yet gone to press, but his memoir on the geology of Hastings was printed and on the eve of publication at the close of the year. Mr. Linsdall Richardson has given much help in the preparation of his memoirs on the water-supply of Somersetshire and Warwickshire, which are passing through the press. His manuscript on the geology of the Moreton-in-the-Marsh Sheet has also received some attention.

Miss E. M. Lind Hendriks has completed the manuscript of a

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list of Classified Geological Photographs specially selected as useful for teaching and demonstration purposes, and Miss Eileen M. Guppy has assisted the Director in preparing a manuscript on tested British roadstones. Miss M. E. Odell has spent much time in improving the registers of our most important fossil collections. Dr. John Horne continues to check and correct the clean-copies and proofs of the maps of the Southern Uplands of Scotland which are being published with revisions due to Dr. Horne and Dr. Peach.

Further assistance in the nomenclature of critical British fossils has been received from Dr. Gertrude Elles (graptolites), Professor Hawkins (echinoderms), Professor Trueman (mollusca), Mr. W. S. Bisat (goniatites), Professor Lang and Dr. Walton (Palaeozoic plants), Professor D. M. S. Watson (vertebrate fossils), Mr. S. S. Buckman (Jurassic cephalopods), and Dr. Stanley Smith (Palaeozoic corals).

Professor R. A. Berry is writing an account of the soils of the Kilmarnock area for inclusion in the memoir on Sheet 22 (Scotland), and Dr. Alex. Scott has prepared a special report on Ball Clays.

Royal Commission on Museums and Galleries

On the 1st July, 1927, a Commission was appointed " to enquire and report on the legal position, organisation, administration, accommodation, the structural condition of the buildings and general cost of the institutions containing the National collections situate in London and Edinburgh," etc.

The Director of the Geological Survey prepared and submitted a memorandum on the Museum of Practical Geology and the collections contained therein. Subsequently he appeared before the Commission and gave evidence.

The following question was asked in the House of Commons on 22nd December, 1927 :—

Sir Charles Oman asked the Under-Secretary of State for the Home Department, as representing the First Commissioner of Works, what are his intentions in view of the dangerous condition of the Museum of Geology in Jermyn Street ?

The Under-Secretary of State for the Home Department (Lieut.-Colonel Sir Vivian Henderson) replied : The Royal Commission on the National Museums and Galleries has represented that the present conditions in Jermyn Street are unsatisfactory from every point of view, and that the transfer of the Geological Museum to an appropriate site in South Kensington should be made at the earliest convenient moment. The Chancellor of the Exchequer and my Noble Friend endorse this view, and hope to give effect to it as soon as financial circumstances permit. (Parliamentary Debates, House of Commons, Vol. 212, No. 144, column 561).

Palaeontology

England and Wales.—The fossils added to the collections during the year numbered 8426 specimens ; of these, 2587 were

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obtained by purchase and by presentation. Conspicuous among the special collections thus acquired was a set of well localized lamellibranchs from various zones of the Inferior Oolite, obtained from Mr. L. Richardson. Dr. C. A. Matley presented a further series of Ordovician fossils from Carnarvonshire.

The examination of the fossils collected in the course of current Survey work has been carried out by Mr. Pringle and Mr. Chatwin, as well as by specialists who are not members of the staff. Dr. Kitchin has spent much time in editorial duties, and he has also been engaged in curatorial and supervision work. Early in the year he paid a visit to the Edinburgh office to confer with Mr. Macgregor and Dr. Lee in regard to matters concerning palaeontological work.

Mr. Pringle identified specimens obtained from localities in 14 sheets in which work was in progress, and furnished completed lists of determinations relating to 8 sheets. He visited sections in the districts of Brampton, Wolverhampton, Shrewsbury, and Merthyr Tydfil, now undergoing revision, and gave assistance to those engaged in surveying the ground. In conjunction with Dr. R. Crookall, he reported on an examination of sections in the Coalbrookdale coal-field, submitting a joint contribution to the memoir on the Wolverhampton Sheet.

Mr. Chatwin prepared the results of his work on the fossils obtained in the Guildford area, for inclusion in the forthcoming memoir (Aldershot). In this connexion he studied further material from the Netley Heath Gravels (specimens presented by Mr. W. Wright and others collected by Mr. F. H. Edmunds). Mr. Chatwin visited sections in Surrey and Sussex and examined part of the core of the Wokingham boring. He also examined and reported on several collections of fossils in private possession, with a view to their acquisition. With the naming and registration of an extensive series of Inferior Oolite fossils, he completed the curatorial work on the Hudleston Collection. He revised four cases of Chalk fossils in the museum, with the assistance of Mr. S. W. Hester, selecting a typical series for arrangement on a zonal basis, and revising the nomenclature.

The fossil-collecting incidental to the current Survey work was carried out chiefly by Mr. Hester, and this entailed visits to localities in Sussex, Surrey, Cumberland, and Lancashire. The work in Cumberland also included the collecting of a representative series of rock-specimens from the Carboniferous system. While in Cumberland, Mr. Hester was assisted by Mr. W. Dewar, who became attached to the department as a General Assistant in June. Since the diversion of his services to the work of inspecting and obtaining records of borings and shaft-sinkings, Mr. A. Templeman has been unable to take any share in the collecting of fossils required during the ordinary sheet-surveying.

During a considerable part of the year Mr. S. W. Morgan gave assistance to Dr. R. Crookall in work connected with the Kidston Bequest of fossil plants.

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In view of the congestion of space in the working-rooms of the Palaeontological Department, it has been necessary to spend much time in carrying out a rearrangement in parts of the stored collections. Mr. Templeman's services have been available from time to time for assistance in furthering this work.

Special attention has been devoted to the important work of registering fossils, and in order to ensure the more steady growth of the registers the services of Miss M. E. Odell, B.Sc., were utilized for about seven months. During that time Miss Odell made good progress, and latterly she confined her attention to those portions which were still unregistered of the large collection handed over some years ago to the Geological Survey by the Geological Society of London.

Many enquiries have been answered, and assistance has been given to numerous research-workers. The specimens of fossils sent out on loan for the purposes of investigation numbered 2177.

SCOTLAND.—1143 specimens of fossils were collected during the year from the Palaeozoic rocks of Scotland and Northumberland. The Scottish specimens were obtained from the Ordovician of Ayrshire, the Old Red Sandstone of the Orkneys, and the Carboniferous of Ayrshire, Berwickshire, Clackmannanshire, Edinburghshire, Fife, Linlithgowshire, and Stirlingshire. The Scottish Carboniferous fossils were found almost exclusively in the cores of borings, while those from the Coal Measures of Northumberland were collected in natural sections.

The collecting of the material from the Old Red Sandstone was carried out by the officers of the Orkney unit, and the remainder by Messrs. Tait, Manson, Eckford, and Strachan, Mr. Manson dealing with most of the borings.

Apart from the Ordovician and Old Red Sandstone fossils (submitted to Dr. G. L. Elles and Prof. D. M. S. Watson, respectively) and the fossil plants, the examination of the specimens obtained was carried out by Dr. G. W. Lee, who also wrote the palaeontological part of the Ardnamurchan Memoir.

New Jurassic exhibits have been added to the Survey collection in the Royal Scottish Museum, and progress has been made in the revision of the obsolete naming of the old exhibits.

Palaeobotany

The chief item of indoor work has consisted in the completion of the catalogue of fossil plants in the Kidston Collection, and this is now ready for the press. Dr. Crookall has also given assistance in checking the lists of plants appearing in the various sheet memoirs issued during the year and those at present passing through the press. Much time has been spent in the identification of the numerous plants collected from localities in the areas covered by Sheets 22, 23, 28, 76 and 85, and from various boreholes which have been under examination. In the course of this work Dr. Crookall has

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prepared and added to the collections 59 photomicrographs and 40 microscope sections.

Thirty-six hand-specimens of fossil plants and 44 microscope slides have been loaned to Dr. R. Florin of Stockholm, and 130 sections of coals to Miss E. Janisch of Cambridge University for research purposes. A selection of 283 microscope slides and 120 hand-specimens have been acquired by purchase and placed in the collections.

Visits have been made, in company with Mr. J. Pringle, to the Coalbrookdale district and to the area represented by the Merthyr Sheet (No. 231), and joint accounts of the palaeontology of the Coal Measures are in course of preparation.

Petrography

The Petrographer has continued with Mr. Richey his work on the Tertiary igneous rocks of Ardnamurchan, and the petrographical description of this region is nearing completion. The descriptive petrography of the Ordovician igneous rocks of the Oswestry district has been completed. Reports have been drawn up on an interesting suite of Lower Carboniferous lavas and tuffs occurring near Cockermouth on the northern side of the English Lake District, and preliminary petrographical work has been carried out on the complex igneous rocks of the Wrekin and adjoining districts. Consequent on the re-survey of the Cheviot Hills preliminary work has been done on the granite, lavas, dykes and metamorphic rocks of that region. The Petrographer has dealt with many inquiries of an official and unofficial nature, identifying and reporting upon material submitted by Survey officers and private individuals. He has furnished information concerning matters of archaeological interest, and, as usual, has reported on material submitted by such other government departments as the Road Board, Government Laboratory, Woolwich Arsenal, and Admiralty, as well as by public bodies.

In the Scottish office Dr. Read and Mr. Phemister have continued their work on the igneous rocks of Lanarkshire (Sheet 23), and Dr. Read has carried out a preliminary examination and classification of the metamorphic rocks of Sutherlandshire (Sheets 108 and 109). Dr. Read has also named and classified some dyke-rocks of the Southern Uplands (Sheet 8).

Mr. MacGregor has completed his detailed account of the post-Old-Red-Sandstone lavas and minor intrusions of Ayrshire for the forthcoming memoir on Sheet 22.

Mr. Bailey has continued his petrographical work on the gneisses of Coll, and Dr. Tyrrell of Glasgow University has completed his account of the petrography of Arran for the second edition of the Memoir on that island.

The number of sliced rock specimens in the collections deposited in London is as follows :—

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English	...	...	14,113
Scottish	...	...	26,301
Irish	...	...	447
Foreign	...	...	2,743
Total		...	43,604

This represents an increase of 1,140 in the registered sliced rocks during the year. Of the corresponding sections, 806 were made in the English office, and 334 were registered to be made in Scotland.

Dr. J. Horne has kindly presented a suite of sections of rocks from Aberdeenshire, and these will, after registration, be incorporated in the Scottish collection.

Photography

Mr. J. Rhodes has been employed taking geological photographs in the districts of Shropshire, Cumberland, Suffolk, Staffordshire and Kent, to the number of 366.

The number of registered negatives is now as follows :—

English Photographs		...	4,216
Photomicrographs	...	...	1,861
Miscellaneous	...	...	1,699

Mr. Rhodes has made 1,639 prints from Survey negatives mainly for incorporation in the Reference-albums but including 58 for reproduction in Survey memoirs, and an addition of 213 lantern-slides has been made to the collection now in process of formation.

Fifteen enlargements of geological subjects were made for exhibition at the meeting of the British Association at Leeds. Mr. Rhodes has also mounted 1,388 prints and 1,249 descriptive forms for use in the English and Scottish Survey libraries.

The albums are now completed to the following registered numbers, each photograph being accompanied by its corresponding descriptive form.

English Series		...	3,819
Scottish Series	...	...	3,003

In Scotland Mr. W. Manson has taken 34 negatives of interesting geological views.

The catalogue of Classified Geological Photographs prepared by Miss Lind Hendriks is completed and ready for the press.

Chemistry

Samples have been sent from Cornwall, Ayrshire, Bute, Lanark and Sutherland for quantitative analysis. The numbers of analyses entered up-to-date in the department's records total :——

English	...	...	340
Scottish	...	...	485
Irish ...	...	...	2

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Welsh	...	...	55
Others	...	...	46
Total	...	...	928

Twenty-seven of the above samples have been analysed during the year and twelve others are in course of completion. Survey Officers have required eight qualitative examinations and many enquiries from various sources have received attention.

The Chemist has, on several occasions, given technical advice to the Officers of the Fuel Research Station with reference to methods for the analysis of coal ashes and of the sintered test cones obtained in the determination of the refractory characteristics of the same materials.

Dr. A. M. Heron (Geological Survey of India) has spent several months in this department, doing analytical work under the direction of the Chemist, on specimens collected in India.

The comparative resistivity of several types of British glass-ware has been practically tested in the laboratory, by long periods of normal use in the course of routine analysis, testing being still continued in order to ascertain which variety would be most suited for work with inorganic reagents.

Museum of Practical Geology

No changes of importance have been made in the Museum during the past year, as pending removal to South Kensington little can be done to initiate alterations or improvements. The total number of visitors during the year was 20,968, of whom 1,389 were Sunday visitors. Thirty-two demonstrations were given by officers of the Museum and Survey to schools and institutions, the aggregate attendance being 615. A special exhibit was prepared for the meeting of the British Association at Leeds in September.

Certain wall cases and table cases have been cleaned and the registration of the collections has been carried forward so far as other duties allowed. Of the Ludlam mineral collection, 1,451 specimens, and of the Lindsey collection 716 specimens were registered and card indexed. Rock sections were prepared, by museum officers, to the number of 89, including several of building stones for the Building Research Station. The exhibit of tested road-stones has been transferred, cleaned and partly re-labelled. Mr. Chatwin has revised several cases of Cretaceous fossils.

For a considerable part of the year the Curator was engaged in geophysical survey work.

The temporary electric lighting has been overhauled. The congestion arising from the lack of space for staff and collections, and the obstruction due to the scaffolding and timber supporting structures have continued to impede the usefulness of the library. During the past year the additions to the library comprised 396 volumes of independent works, 2,879 volumes and parts of

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serials, 693 maps, 299 pamphlets and 514 Geological Survey photographs. The library is expanding but is much hampered by lack of space. It continues to be much used by mining engineers, geologists and other professional enquirers, and the attendance of students wishing to consult maps and geological books is constantly increasing.

List of Donations during the year 1927

ARKELL, D. J., ESQ.—Specimens of strontianite.

ASHCROFT, F. N., ESQ., M.A.—Specimens of prehnite from Switzerland.

BARROW, G., ESQ., F.G.S.—A specimen of the Basement Bed of the London Clay (with fossil shells) from Lane End, High Wycombe, Buckinghamshire.

BOLTON, H., ESQ. D.Sc., F.G.S.—A series of marine fossils from the Coal Measures of the Bristol coalfield.

BROWN, G. F., ESQ.—A series of Chalk fossils, chiefly Echinoderms, from various localities in Surrey.

COLLETT, H. E., ESQ.—Rough sapphire crystals, from Queensland, Australia.

COOKE, H. C., ESQ. (Canadian Geological Survey).—Four specimens of dalmatianite, from the Annular Gold Mine, Western Quebec, Canada.

DAVIS, A. G., ESQ.—A series of Chalk fossils from the rock-band in the base of the *Micraster cortestudinarium* Zone, from various sections in North-east Surrey.

DEWEY, H., ESQ., F.G.S.—A series of bones and teeth from the Pleistocene of Plymouth Caves, Devon.

DIX, MISS E., M.Sc., and A. E. TRUEMAN, D.Sc., F.G.S.—Eighty-five specimens of rocks and fossils from boreholes in the Cwmgorse valley—75 from No. 1 borehole, 10 from No. 2 borehole.

DUGDALE, G. R., ESQ.—Native gold in talc and telluride gold ore, from Kalgoorlie.

DUNBAR, MAJOR R. M.—Gold-bearing quartz from Masai Province, Kenya Colony.

FLEMING, J., ESQ.—Tourmaline, cut stone, particoloured.

GARWOOD, PROFESSOR E. J., Sc.D., F.R.S.—Two specimens of basalt and one tuff specimen from Cumberland; also three basalt specimens from Roxburgh.

GIROUARD, COLONEL SIR PERCY, K.C.M.G., D.S.O., R.E.—Two Ammonites from 30 ft. above the base of the Chalk Marl, at 50 ft. above O.D., at Asheacham House, Beddingham, Sussex.

GOODENOUGH, CADET F. C., R.N.—A flint nodule containing the rare sponge *Aulaxinia costata* Hinde, from the Quadratus Zone of Whiteparish (about 10 miles from Salisbury), Wiltshire.

HAYES, DR. A. O.—A series of twenty-five specimens to illustrate the occurrence of iron ore at Wabana, Newfoundland.

HENDRIKS, MISS E. M. LIND, B.Sc.—Three rock specimens from Mullion Island, Cornwall.

HEWITT, H. DIXON, ESQ., F.I.C.—Eight specimens of Lower Greensand fossils from boulders in the Thetford Glacial Gravels at Thetford Warren, Norfolk.

HORNE, DR. JOHN, F.R.S.—One hundred and fifty-six rock sections prepared from Scottish rocks.

JACK, G. H., ESQ., M.INST.C.E., F.R.I.B.A., F.G.S.—A specimen of *Pterygotus sp.* from the Old Red Sandstone of Abbeydore, south-west Herefordshire.

LANG, PROFESSOR W. H., F.R.S.—Plant remains from the Middle Old Red Sandstone of Loch Brora, Sutherlandshire, and Hillhead Quarry, Dalcross Station, Inverness.

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LESTER, DR. A. R.—A specimen of stichtite and asbestos.

MATLEY, C. A., ESQ., D.Sc., F.G.S.—A series of Ordovician fossils from the Lleyn district of Carnarvonshire.

MOORE, E. W. J., ESQ., B.Sc., A.I.C.—Two specimens of *Goniatites subcircularis* S. A. Miller, from the Bowland Shales (Spirale Zone) of Dinckley, Lancashire; and a portion of a bullion containing numerous specimens of *Homoceras striolatum*, var. *subglobosum* Bisat, from the Sabden Shales (H) in the Millstone Grit Series of Gill Beck, near Colne, Lancashire.

OGILVIE, SIR F. G., C.B., LL.D., M.A., B.Sc.—Specimens of fossil wood and fossil sponge from the Bargate Stone south of Shere, Surrey.

PORTER, R. H., ESQ.—Specimens of daphnite, cassiterite, wollastonite, orthoclase and mica, from Redruth, Cornwall.

POWELL, L. S. ESQ.—Specimen of talc from limestone, from a quarry N. of La Rochette, Savoy.

PRINGLE, J., ESQ., F.G.S.—A specimen of *Cleoniceras morgani* Spath (sp. nov.), from the Lower Albian (Regularis subzone) of Leighton Buzzard, Bedfordshire, figured by Dr. L. F. Spath, 'Ammonoidea of the Gault,' pl. xvii, fig. 7; pl. xviii, fig. 5. (Palaeont. Soc.).

PRESTON, MISS L. F. N.—A series of Roman marble specimens.

SANDISON, W. G. W., ESQ.—Chlorite rock from Shetland.

SMITH, H. H., ESQ.—Tourmaline in pyrite, from Meldal, Norway.

SOUTH AFRICA, THE DIRECTOR, GEOLOGICAL SURVEY, UNION OF.—A series of platinum-bearing rocks and other minerals and rocks from South Africa.

SPENCE, MESSRS. PETER, & SONS, LTD.—Specimens of leucite lava and sample of leucite from Farnworth, Widnes, Lancashire.

STATHER, J. W., ESQ., F.G.S., *per* T. SHEPPARD, ESQ., M.Sc., F.S.A. (SCOT.), F.G.S.—A specimen of *Inoceramus lingua* Goldfuss, from the Upper Chalk (Quadratus Zone) of White Hill Quarry, Bridlington, Yorkshire.

TRUEMAN, A. E., ESQ., D.Sc.—*see* MISS E. DIX.

TULLY, B. J., ESQ., F.G.S.—Brochantite with chalcanthite from Chile; also opal doublet, synthetic emerald, etc.

TUNNEL PORTLAND CEMENT COMPANY, THE.—A series of specimens illustrating the manufacture of Portland Cement.

WALKER, DR. F.—Four specimens from thick sill in Shiant Isles.

WARE, W. D., ESQ.—A series of Lamellibranchs from the Coal Measures of various localities in Glamorganshire.

WHITELEY, J. H., ESQ., F.I.C.—Vogtite-silica slag.

WOODS, H., ESQ., M.A., F.R.S., F.G.S.—A series of fossils from the Upper Chalk (Mucronata Zone) of Cottishall, Norfolk.

WORSFOLD, F. H., ESQ., F.R.I.B.A.—A specimen of fossil fruit from the London Clay of Tankerton Bay cliffs, Whitstable, Kent.

WRIGHT, W., ESQ., F.G.S.—Specimens of fossiliferous ironstone from the Gravels at Netley Heath, Surrey.

JOHN S. FLETT,
Director.

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II. DISTRICT REPORTS

(A)—ENGLAND AND WALES

1. LONDON AND SOUTHERN DISTRICT

HENRY DEWEY, District Geologist.
H. G. DINES, A.R.S.M., A.M.INST.C.E.
W. LLOYD, B.Sc.
F. H. EDMUNDS, M.A.
} Geologists.

DURING 1927 routine field work was suspended in order that parts of the geological lines in several districts could be revised for the preparation of colour-printed editions of hand-coloured maps. Memoirs describing these maps were written by Professor P. G. H. Boswell and Messrs. H. J. O. White and Linsdall Richardson. Mr. Dewey spent several weeks in inspecting and revising areas near Hastings, Dover and Ramsgate, and in preparing the maps and memoirs for the press. The following were published during the year :—Special Map of the London District, and the Ipswich map and memoir ; while dry-proofs of the following maps were sent for engraving to the Ordnance Survey Office :—Aldershot ; Dover ; Ramsgate ; Sudbury ; Hastings and Dungeness. Colour-printed proofs of Felixstowe, Woodbridge, Hastings and Dungeness have been passed for printing.

The manuscript of the memoir on ' Aldershot and Guildford ' by Messrs. Dines and Edmunds is nearly complete, while that on ' The Wells and Springs of Sussex ' by Mr. Edmunds is ready for the printer.

Enquiries relating to water supply, building sites, soils and engineering problems have greatly increased in number, and upwards of 300 were dealt with. The principal related to proposed tube-railways under London and Southampton and tunnels under the Thames. The best sites for supplies of water for public bodies were also considered, while advice was given in numerous cases of foundering walls due to moving subsoil.

Mr. Dines spent some time in the early summer revising boundary lines of the drift deposits and in tracing the junction of the Middle with the Upper Chalk in the valley of the Dour and its tributaries near Dover. In the autumn he surveyed the drift deposits of the northern part of the Cotteswold Hills (Sheet 217), and has demonstrated the occurrence of boulder-clay and other glacial deposits as far south as the limits of the map.

In the spring Mr. Edmunds revised some boundary lines of the

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Purbeck Beds, the Fairlight Clays and the Ashdown Sand around Hastings and Battle, and was able correctly to represent the faulted area in Hastings town. Clear exposures showed the faults in the excavations for the Music Pavilion. Much assistance in this work was rendered by Mr. W. J. Lewis Abbott, who generously lent his notes and specimens, collected over a number of years, to the Survey.

In the summer Messrs. Dines and Edmunds surveyed the drift deposits west of Deal and in the Isle of Thanet. They mapped ridges of brick-earth overlying Coombe deposits and trending parallel with the coast near Deal. In this brick-earth, at Coldblow Farm, Walmer, a working-floor of flint implements was discovered, at a depth of 12 feet from the surface. The implements are chiefly scrapers and cores. North-west of Ramsgate a wide area covered with Thanet Sand has been mapped by Mr. Edmunds.

The occurrence in the Netley Heath deposits of isolated lumps of ferruginous sandstone with a fauna comparable with that of the Scaldisian and Poederlian horizons of the Upper Pliocene [1] led Mr. Edmunds to re-investigate the tracts of similar detritus at Lenham, Paddlesworth, Folkestone and Beachy Head. Mr. Lewis Abbott had collected such material at widely different heights on Beachy Head and the neighbouring Downs, and had published a paper in which it was described.[2] Mr. Edmunds had the opportunity of examining such ferruginous sandstone in the Beachy Head district, where it occurs in considerable quantity, and although it is largely unfossiliferous some blocks yielded marine fossils of Pliocene age. The fossils collected by Mr. Lewis Abbott are similar to the fauna at Lenham, but different from that at Netley Heath. The sections at Lenham on re-examination showed three deep pipes in the Chalk infilled with a disordered mass of sand and loam, in which are embedded numerous lumps of ferruginous sandstone and large noded and battered flints: casts of fossils also were found. In no sense can these materials be called beds: they represent merely the infilling detritus of solution cavities in the Chalk. Mr. Searles V. Wood (senior) was aware of this fact, for in an unpublished letter to Mr. Whitaker dated 26th February 1866, now in the possession of the Survey, he says "In regard to the Lenham fossils all that I know of them was given in Mr. Prestwich's paper where his opinion of their Crag character was more strongly expressed than my own. Many of the casts bore considerable resemblance to Crag species but I then considered and still consider it extremely hazardous to attempt to identify species by casts alone. My leaning would be to think them somewhat older than the Crag but what I observed concerning the fossils themselves was in reference only to their palaeontological character and not in reference to the age of the bed containing them which may be of *very recent* date and contain these casts only as derivatives—indeed they came from no actual deposit

[1] Chatwin, C. P., *in* 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, p. 157.
[2] 'Pliocene Deposits of the South-east of England,' *Proc. Prehist. Soc. of E. Anglia*, vol. ii, 1915–16, pp. 180–186.

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but only from the red sand filling the pot-holes on the edge of the Chalk scarp."

Professor P. G. H. Boswell has examined the heavy minerals from the supposed Pliocene and some other deposits on the North and South Downs but finds the suites similar in every case with the exception of those from the ferruginous sandstone of Netley Heath.

Mr. Lloyd was transferred temporarily from the Manchester field unit to Torquay to revise the geology of that area with the view of preparing a second edition of the Torquay memoir, the first edition having run out of print several years ago. He has made good progress with the work, but recent advances in petrological study of the Devonian rocks, and the large number of new sections render rapid progress difficult.

H. DEWEY.

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2. MIDLANDS DISTRICT

T. C. CANTRILL, B.Sc., District Geologist.
C. B. WEDD, B.A.
R. W. POCOCK, M.Sc.
T. H. WHITEHEAD, M.Sc., A.R.C.Sc. } Senior Geologists.
T. ROBERTSON, B.Sc., Ph.D., A.INST.M.M., Geologist.

DURING the past season (1927) work has proceeded in the Shrewsbury district. North of the River Severn Mr. Pocock has mapped the area around Leighton, Wroxeter and Atcham, and south of the river around Shineton and Cressage. He has found it necessary to devote much time to the study of the complicated ground lying between the Wrekin and Charlton Hill. Mr. Whitehead has surveyed an area in the south-west corner of the Sheet (152), extending from Pontesbury southward.

Pre-Cambrian.—Mr. Pocock finds that the Uriconian rocks of the Wrekin have an average northerly dip of 45° and can be divided into groups of bedded ashes, conglomerates and rhyolites. The dolerite mass near The Cottage, at the northern end of the Wrekin, which Callaway regarded as " an ancient volcanic vent," maps out as a group of basic dykes, with an approximately north and south strike and steep easterly dip, cutting almost at right angles across the strike of the Uriconian ashes and conglomerates. In plan these dykes show a curved outcrop due to the high relief of the ridge. Above Wrekin Farm a dyke of similar character traverses the ashes on the north-west side of the Wrekin Fault, and another occurs within the mass of the rhyolite that forms the central and highest portion of the hill. As none of these dykes has been found to penetrate the Cambrian Quartzite, their pre-Cambrian age may be assumed with some confidence.

Uriconian rocks are thrown down by the Wrekin Fault all along the north-western side of the hill.

The Uriconian rocks of Charlton Hill, Overley and Wrockwardine have also been examined by Mr. Pocock. The Charlton Hill area is much complicated by faulting, in continuation of the line of the main Church Stretton fault-complex. The ashes and conglomerates of the hill are traversed by a set of felsite dykes. Similar dykes occur in the Wrockwardine area and at the south-western end of the Wrekin.

Volcanic rocks of pre-Cambrian age occur also in the area surveyed by Mr. Whitehead in Pontesford and Earl's Hills,[1] and at

[1] See W. S. Boulton, ' The Igneous Rocks of Pontesford Hill, Shropshire,' *Quart. Journ. Geol. Soc.*, vol. lx, 1904, p. 450.

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the Lyd Hole to the east of these hills. This area contains, in addition, a considerable tract of sedimentary rocks belonging to the group called by Lapworth [1] the Wentnor Series, or Western Longmyndian. In the neighbourhood of Oakswood these rocks include three conglomerates, of which the lowest in apparent position contains mainly quartz and quartzite pebbles with only rare rhyolite fragments. The middle conglomerate contains pebbles of rhyolite and felsite to the extent of at least 50 per cent; whilst in the apparently highest also such pebbles are numerous, but of smaller average size. The dip in the area east of Pontesford and Earl's Hills is to east-south-east at angles ranging from 60° to 70°. This direction of dip has been found to persist for about 1½ miles along the strike and through at least 3,500 ft. of strata. As the outcrops are followed southward the dip becomes steeper until, at Paulith Bank, the beds are vertical. Farther south still the dip is west-north-westward at high angles.

These Longmyndian grits and conglomerates are traversed by dislocations that appear to be of the nature of tear-faults. These faults, and the joints parallel to them, have formed the channels whereby the barytes and copper-bearing lodes have been injected.

Cambrian.—Further examination by Mr. Pocock of the district between the Wrekin and Charlton Hill has revealed the presence of an important suite of Cambrian rocks comparable, in part, with those of Comley described by Mr. E. S. Cobbold,[2] who has undertaken the identification of the fossils from the present area and has visited most of the sections.

The Wrekin Quartzite, well known to occur at Rushton and at Charlton Hill, has now been traced through the intervening ground, where it rests on the Rushton Schist. In an old roadside quarry east of Rushton the lowest beds of the Quartzite, consisting of alternations of quartzite and dark grey shale, rest on an uneven floor of Uriconian felsite.[3]

Faulted outcrops of the Quartzite rest also upon the Uriconian rocks on the south-western and southern sides of Charlton Hill and of the small subsidiary hill to the south.

The Quartzite is overlain, near Rushton, by about 500 ft. of Lower Comley Sandstone, at the top of which, in the Charlton Hill branch of Dryton Brook, occurs a greenish micaceous sandstone containing abundant fragments of *Callavia callavei* (Lapworth) and other fossils, which suggest a reference to the Callavia Sandstone (Horizons Ac 1 & Ac 2 of Comley).[4]

Fragments of a fossiliferous calcareous grit from the same locality are comparable, in their lithological character and fauna,

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[1] Lapworth, C., and W. W. Watts, 'Shropshire,' in 'Geology in the Field,' *Geol. Assoc.* Jubilee Vol., 1910, p. 739 (see p. 748).

[2] 'The Stratigraphy and Geological Structure of the Cambrian Area of Comley (Shropshire),' *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927, p. 551.

[3] Our attention was drawn to this fact by Mr. T. Hirst.

[4] A few fossils were collected, apparently from this locality, by Mr. J. Rhodes under the guidance of Prof. Charles Lapworth in 1892-3.

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with the *Microdiscus bellimarginatus* Limestone (Horizon Ac 3 of Comley). Other fragments of a dark granular phosphatic limestone with fossils may perhaps be referred to the Lapworthella Limestone (Horizon Ad of Comley).

These Lower Cambrian beds in Dryton Brook appear to dip southward at about 30° and are succeeded by Middle Cambrian glauconitic grits and shales. A calcareous block in the stream a few yards south of the last locality is crowded with well-preserved fragments of *Paradoxides* (perhaps two or more species) and other fossils. Mr. Cobbold considers that the fauna indicates Horizon Ba 1 of Comley, i.e., the *P. groomi* conglomerate and grit.

In the Rushton branch of Dryton Brook another calcareous bed yields a well-preserved fauna indicating, in Mr. Cobbold's opinion, a horizon high up in the Paradoxidian.

The Middle Cambrian beds have a lesser angle of dip than the Lower Cambrian, and may prove to be unconformable. They crop out again in the fields to the south of Charlton Hill.

Shales with *Acrotreta* and a brachiopod have been found on the east flank of Charlton Hill, but their horizon has not yet been determined.

A large block of black limestone, 'stinkstone,' in Dryton Brook, on the line of the Wrekin Fault, may be *in situ*. It is crowded with detached portions of trilobites and is provisionally referred by Mr. Cobbold to Zone No. 5 of Westergård [1] [Upper Lingula Flags]. This would indicate that the block belongs to a horizon well down below the Shineton Shales but above those with *Orusia lenticularis* and *Parabolina spinulosa*.

Purplish shales, probably Upper Cambrian, are exposed in Dryton Brook just north of the boundary of the Coal Measures of the Dryton Coalfield, i.e., just north of the Longwood-Dryton lane.

Mr. Pocock has also mapped the Upper Cambrian shales in the Leighton and Shineton areas, and Mr. Whitehead those in the Habberley valley as far as the southern border of Sheet 152 (near Gatten). Mr. Whitehead concludes that the junction of these Shineton (Habberley) Shales with the Longmyndian rocks to the east is probably a fault.

Ordovician.—A small area of rocks of Arenig age has been mapped by Mr. Whitehead near the south-west corner of the Sheet. These consist, in ascending order, of: (1) Stiper Quartzite, (2) Mytton Beds, flaggy sandstones and sandy shales, (3) Hope Shales, black and grey shales. The outcrops within the area surveyed have not yielded fossils owing to the cleaved condition of the rocks; but they form part of a larger area in which the succession was established by C. Lapworth.[2]

Ordovician shales crop out also in the valley east of Pontesford

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[1] Westergård, A. H., 'Sveriges Olenidskiffer,' *Sveriges Geologiska Undersökning*, Ser. Ca., No. 18, 1922.

[2] See 'Summary of Progress' for 1915 (*Mem. Geol. Surv.*), 1916, p. 37.

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and Earl's Hills, where they rest unconformably, and with a basal conglomerate, upon pre-Cambrian rocks. Further collecting is required before the precise stratigraphical position of these shales can be determined; but there is some evidence that they belong to a horizon lower than that to which they have hitherto been assigned.[1]

Silurian.—Mr. Pocock has surveyed three divisions of the Valentian (Arenaceous Beds, Pentamerus Beds, and Purple Shales) southward from the Carboniferous overlap at Wenlock Wood to the River Severn, and south of the river to Shineton Brook.

The basal portion of the Upper Llandovery Sandstone just enters the area mapped by Mr. Whitehead; but almost the only exposure is in a small outlier situated 400 yds. south of Callow Hill Camp.

Carboniferous.—The area surveyed by Mr. Whitehead includes Upper Coal Measures near Pontesford and Pontesbury. There are, however, no natural exposures, and little or no information is available concerning the small collieries that were formerly worked, chiefly for coal to smelt the lead ore of the Shelve district.

Trias.—The Lower Mottled Sandstone that rests against the north-western flank of the Wrekin is believed by Mr. Pocock to have only a narrow outcrop about half a mile wide, while the drift-covered area round Aston and Cluddley is probably underlain by the Keele Beds, and not, as shown on the Old Series map, 61 N.E., by Trias.

A small area of Pebble Beds occurs at Eyton, faulted on the east against Uriconian rocks and overlying Lower Mottled Sandstone on the west. The Lower Mottled Sandstone is well exposed in the left bank of the Severn and is seen again in Bell Brook, west of Uppington.

Superficial.—The ground between the Wrekin and Overley Hill is much obscured by loamy boulder-clay with mounds and patches of sand; while, west of Charlton Hill, the solid rocks are almost completely covered with moundy drift.

In the Severn valley three distinct terraces have been mapped at heights of about 10, 20, and 45 ft. above the alluvium.

Brown boulder-clay covers much of the country surveyed by Mr. Whitehead. On the watershed between the Severn and Teme drainages, near Gatten, the drift reaches a height of over 1,100 ft. The stones in the boulder-clay are chiefly such as might have been derived from the Stiper Quartzite ridge or the area immediately to the west of it; except that, east of the Habberley valley, fragments of Longmyndian grit and of dolerites like the intrusions of Pontesford Hill are present.

South Wales

In continuation of the revision in progress in the South Wales Coalfield Dr. Robertson has been engaged in the Merthyr Tydfil

[1] Watts, W. W., *Proc. Geol. Assoc.*, vol. xxxvi, 1925, pp. 340, 343.

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district (Sheet 231). As the memoir on that area is out of print the opportunity is being taken to bring the account of the geology up to date, especially as regards the Carboniferous rocks, which occupy about two-thirds of the district and include some 70 square miles of the northern portion of the coalfield. The remainder consists of Old Red Sandstone and provides not only delightful mountain-scenery but also an abundant water-supply, of which the larger towns farther south, including Cardiff, take full advantage.

Re-examination of the Carboniferous Limestone in the light of the Avonian sequence has revealed some interesting points regarding the westward development of the intra-Avonian unconformity. The progressive mining districts of Merthyr Tydfil, Aberdare, the Vale of Neath, the Dulais valley, and the higher portion of the Swansea valley illustrate the transition westward from steam coal to anthracite, a problem to which it is hoped to devote some further attention from the geological point of view.

T. C. CANTRILL.

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3. YORKSHIRE DISTRICT

Headquarters: York

C. E. N. Bromehead, B.A., District Geologist.
G. V. Wilson, B.Sc. } Senior Geologists.
D. A. Wray, Ph.D., M.Sc. }
J. V. Stephens, B.Sc., B. Eng. } Geologists.
Wilfrid Edwards, M.A. }

OWING to the absence for three months of two members of the staff, Messrs. Stephens and Edwards, in Orkney and the preparation of the memoir on the Huddersfield Sheet, progress with the resurvey of the Glossop Sheet (86) has been slow. The ground was allotted as in the previous year.[1] Mr. Edwards was mainly concerned with the Kinderscout Grits and the beds below them. He finds that the thickness of these grits north of Longdendale is about 550 ft., including three to five shale partings. The ground is much more faulted than was indicated on the original survey; a north and south line of anticlinal folding along the Tame valley from Saddleworth to Mossley (the 'Pennine Anticline') has been examined but not yet completely mapped. East of the fold the faults follow two dominant directions, north-north-west and north-north-east, but east of a line from Middle Edge Moss to Rhodeswood Reservoir the faulting is somewhat less, the trends become north-west and north-east and some east and west faults appear.

In the country around Glossop the most remarkable feature discovered by Mr. Stephens is the paucity of sandstones in the Middle Grits; at Chunal, 1½ miles south of Glossop, the Huddersfield White Rock is represented by 40 ft. of sandstone and grit, but beneath this the three marine bands characterised by mut. α, β and γ of *Reticuloceras reticulatum* Bisat have all been detected and are separated by only 160 ft. of shale with no sandy beds.

A confusing area between Meltham and Holmfirth has been approached from various sides by Mr. Bromehead, Dr. Wray and Mr. Edwards. There appear to be unusual developments of ganister, coal and sandstones in the Middle Grits: Dr. Wray notes that on the horizon of the Beacon Hill Flags a bed of ganister up to 12 ft. thick is being worked at Royd Edge and Banister Edge, Meltham. It immediately overlies a 9-in. seam of coal locally known as the Lower Meltham Coal, while in the shales above it there occurs a marine band with *Reticuloceras reticulatum* mut. γ Bisat. Above

[1] 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, pp. 46, 47.

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this band is a representative of the White Rock with the usual ganister and coal at the top. Mr. Bromehead finds the *cancellatum* marine band about 20 ft. above this, as usual, but it is succeeded, between Harden and Wolfstones, by a sandstone unrepresented in other parts of the district, which also has a ganister top with a coal and is separated by shales from the overlying Rough Rock. This new sandstone was called "Bed A" by Green,[1] and the coal above it he termed the Upper Meltham Coal. There were thus two names, Upper and Lower Meltham Coals, for three seams, of which the middle one has been given either name.

The Rough Rock, which makes a broad spread on Honley Moors, is of a very variable nature in Honley Wood; it consists of alternations of flags and coarse massive grit. In this area the flag horizon is by no means confined to the base of the series and it is impossible to draw a definite line between it and the Rough Rock proper. Around Holmfirth and Hepworth no flags have been distinguished.

The lower part of the Lower Coal Measures is similar to that found in the Huddersfield Sheet; the marine band above the thin coal at the base is exposed near Hepworth, and Mr. Wilson finds that excellent exposures are to be seen on both sides of the Little Don River half a mile below Langsett, and also in the cutting on the old railway belonging to Sheffield Corporation a few yards north of where it crosses the road about a quarter of a mile east of Langsett; the bed is about 1 ft. thick and highly fossiliferous.

To the south of Skelmanthorpe the Better Bed Coal is absent, being represented by a fireclay only, but the Penistone Flags with some unimportant seams of coal make their appearance and have been mapped through Cumberworth and Ingbirchworth to the Penistone neighbourhood. The Whinmoor Coal, usually in three beds, now becomes important and may be the equivalent of the Beeston, but the correlation of this and the several coals in the Middle Coal Measures, as found in the country between Denby Dale, Clayton West and High Hoyland, with those of the ground already mapped to the north, is attended with considerable difficulty. At the time of the previous survey little was known of this area as, owing to the relative thinness and poorness of the seams, it had not been developed; Green dismissed it as 'obscure' but tentatively correlated a thin coal locally known as the Clayton Common Coal with the Blocking Bed Coal of the country to the north and with the Silkstone of the south (*op.cit.*, p. 281). Recent developments in this area suggest to Dr. Wray that the Clayton Common Coal is more strictly correlative with the Wheatley Lime Coal and that a thin unnamed seam represents the Blocking Bed. The difficulty that attends any effort to correlate the succession of this with adjoining areas arises from the fact that the whole of the seams between the Silkstone and the Parkgate fall off in quality and the general succession changes much in character. Whatever the

[1] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1879, pp. 56, 57.

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conditions may have been which produced this change, they were repeated during the formation of each one of the coal seams. Dr. Wray discussed the changes in the Barnsley Bed, which crops a few miles farther east, in last year's *Summary of Progress*,[1] and as facts accumulate he may be led to a satisfactory explanation: the line of change is of great importance, as it forms the boundary between the West Yorkshire and the South Yorkshire coal districts. The structure is also in need of elucidation: from Denby Dale to Scissett the Whinmoor Coal outcrops near the bottom of the valley, but a coal near the top of the hill on the south, some 250 ft. higher, was also called the Whinmoor on the original survey and shown as surrounded by a triangle of faults; the succession is, however, normal and unfaulted, the upper seam being probably the Parkgate, while representatives of the Wheatley Lime or Silkstone Four Foot and of the Blocking Bed or Silkstone have both been worked recently between it and the Whinmoor. It is clear that in this region there will be considerable alterations in the mapping; unfortunately it is certain that the Silkstone Coal is absent in some areas and the boundary between Middle and Lower Coal Measures will there be a hypothetical line.

Mr. Wilson has continued to watch developments in the Concealed Coalfield; much of his work will be found in Appendices VII & VIII in Part II. An important item has been the examination of the fresh water mollusca, collected from the bore at Wressell by Mr. Manson in 1914, by Dr. A. E. Trueman. He reports that the types are such as are usually found in the measures that occur above the Barnsley Bed. This result is most interesting in its relation to the northern margin of the Yorkshire Coalfield, as it shows that the beds there are well up in the Middle Coal Measures and not Lower Coal Measures as was formerly thought to be the case.

Through the courtesy of the engineer in charge, important cuttings on the London, Midland and Scottish Railway in Derbyshire (see Appendix VI, Part II) and Yorkshire have been examined. At Sandal an interesting exposure of a marine bed in the Middle Coal Measures was noted at a point about 100 yds. south-west of Two Lands Bridge, which crosses the railway about 1¾ miles north-east of Sandal and Walton Station. This section of the line has recently been widened, and the cutting has been earthed over again. The structure of the ground is much obscured by faulting, and the relations of the marine bed to the surrounding rocks are difficult to make out. The section showed a variable bed of limy cank up to 9in. thick resting on a 3-in. coal and overlain by fissile, very rotten shales, which yielded *Orbiculoidea* and fragments of *Pterinopecten*. In many ways the section is similar to that seen in Cudworth Brick Yard, where a bed which is supposed to be the Mansfield Marine Bed is exposed.[2] The marine bed there lies above the Oaks Rock of that district. As far as can be made out the exposure in the rail-

[1] Appendix VI, pp. 127–37.
[2] 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, p. 62.

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way cutting lies on the downthrow side of a fault, which runs parallel to and directly along the course of the line. Across the fault the base of the Oaks Rock is seen, so it is evident that the marine bed lies above that rock, and it seems highly probable that it is the Mansfield.

The number of enquiries on water-supply and other matters continues to increase, and we are indebted to several boring firms and to Professor P. F. Kendall for a great number of records of bores. For Derbyshire Mr. Stephens is preparing a Water-Supply Memoir which is nearing completion.

C. N. BROMEHEAD.

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4. LANCASHIRE DISTRICT

Headquarters: Manchester

W. B. WRIGHT, M.I.M.E., District Geologist.
R. L. SHERLOCK, D.Sc., A.R.C.Sc., Senior Geologist.
W. LLOYD, B.Sc.
L. H. TONKS, M.Sc.
R. C. B. JONES, M.C., M.Sc. } Geologists.

IN the Manchester area, Sheet 85, progress has been slow owing to the absence throughout the year through illness of one member of the staff, and the detailing of a second, Mr. Jones, for four months work in the Orkney Islands. Some heavy work on the examination of underground tunnels has been undertaken by Mr. Tonks. Mr. Wright has been engaged in a study of the fossil remains obtained from these tunnel sections and from the limited surface exposures, but the results are not yet available for publication. The re-surveying of Sheet 85 having been completed the six-inch maps of the area are being produced, while a start has been made on Sheet 84 (Wigan).

In the *Summary of Progress* for 1925 mention was made of the rapid variation of the lower beds of the Middle Coal Measures across the line of the Irwell Valley Fault. Dr. Sherlock has found an instance of similar variation in the metals above the Rams Mine in the area between Little Lever and Radcliffe on the north, and Swinton on the south, and has been able to show that the line of this great fault does not in this instance, directly at any rate, control the variations in the strata.

In the Little Lever and Radcliffe district the Three Yards Mine is a well-known seam, but south of the Irwell Valley Fault the coal is not recognised. Instead we find a group of coals—the Shuttle, Crumbouke, Ockley, and Brassey or Little Mines.

In the northern area the Three Yards is represented at Kennel Pit, in the west of Radcliffe, by two seams separated by 2¾ ft. of 'bin.' At Allen's Green Colliery the Three Yards is much the same, but there also appear three coals separated from one another by fireclays and from the Three Yards below by about 40 ft. of strata. These three nameless coals appear to represent the Crumbouke, Shuttle, and Ockley of the southern area. In Radcliffe, south of the Irwell, the Spring Well Pit showed the Three Yards as before with the three coals above separated from it by 28 ft. of strata. At Meadow Pit, Stand Lane Colliery, the three new seams are separated from the Three Yards by only 1¾ ft. of fireclay, and the name Three Yards was given to the whole group.

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FIG. 1.—*Comparative Sections of the Three Yards Group in the Radcliffe-Swinton District.*

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In the southern area we find a group of coals at Bridgewater and Linnyshaw collieries, Walkden, similar to that at Stand Lane. The top member is here named the Crumbouke and the bottom one the Brassey, while the name Ockley is given to an intermediate coal. At Newtown Colliery there is a top seam, the Shuttle, corresponding to the Crumbouke of Bridgewater, and midway between the two is the Four Feet Mine. At Pendlebury Colliery there are three coals, the top one called the Shuttle and the bottom one the Crumbouke, with only about 2 ft. of strata between each coal and the next. Finally, at Clifton Hall Colliery the group of coals is condensed into two seams, the Shuttle above and the Crumbouke below, with only a fireclay between them.

It appears that the Three Yards of the northern area is represented by the Brassey (Little) Mine of the southern area and that at Pendlebury this has disappeared altogether, while at Clifton Hall it may be represented by a fireclay 28 ft. below the Crumbouke.

In one-inch Sheet 84 (Wigan) a small area has been surveyed by Mr. Tonks around Ormskirk. Over most of this area the surface is boulder-clay and Shirdley Hill Sand. The boulder-clay gives rise to heavy clay and sandy clay soils with stones. In a few places the clay soils are so heavy that they are left as permanent pasture; but on the rising ground, downwash, and a thin cover of Shirdley Hill Sand mix with the boulder-clay to give lighter soils.

Mapping has also been commenced by Mr. Jones on Sheet 84 to the south and east of Horwich, where a considerable area is covered by Lower Coal Measures. These are much faulted and are obscured by drift in the lower ground. Little mining has been done, and the measures for the most part appear to be barren, except for the Upper Mountain Mine, which has been worked in a small area about Green Hill.

W. B. WRIGHT.

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5. CUMBERLAND DISTRICT

Headquarters: Whitehaven

BERNARD SMITH, M.A., Sc.D., District Geologist.
E. E. L. DIXON, A.R.C.Sc., B.Sc. } Senior Geologists.
T. EASTWOOD, A.R.C.Sc. }
F. M. TROTTER, M.Sc. } Geologists.
S. E. HOLLINGWORTH, M.A., B.Sc. }

IN Cumberland the mapping of the six-inch sheets covering Sheet 18 (Brampton) has been completed:—by Mr. Trotter in the area north-east of Carlisle, and by Mr. Hollingworth on the borders of Northumberland west of Alston. Apart from brief visits to the field the other officers have been chiefly engaged in the production of maps and memoirs. Several shafts and bores for coal or haematite have been examined and many old records obtained. Mr. Eastwood took part in a conference of agricultural research workers held in September at Wykeham near Scarborough.

In November the office was closed and staff and stores transferred to Headquarters in London.

BRAMPTON SHEET

Mr. Trotter finds that an outcrop of the widespread Carboniferous rocks of the Bewcastle Sheet (12) protrudes into the New Red rocks of the Brampton district (Sheet 18) east of Hethersgill, where it forms a triangular area with its apex pointing south in the neighbourhood of Walton Moss. On the east the rocks are bounded by a post-Triassic fault (the Crosby Fault), whilst on the west they are succeeded by unconformable New Red rocks, the junction being exposed in a section in the Hether Burn, about 1 mile east of Hethersgill. These rocks are considered to belong to the Fell Sandstone Group.

Farther north-west, to the east of the faulted junction with New Red rocks at Brackenhill on the River Lyne (Sheet 12, 1½ miles north-north-east of Kirklinton) exposures of sandstones, shales and thin marine limestones probably represent the upper part of the Fell Sandstone Group. One bed of sandstone is at least 200 ft. in thickness.

Mr. Hollingworth has completed the survey of a tract of Lower Carboniferous rocks just beyond the southern margin of Sheet 18.

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Here the beds lie wholly within the Middle and Upper Limestone Groups. Good sections of the Scar Limestone and overlying beds are exposed in Gilderdale (Sheet 24), where the top of this limestone is characterised by a bed rich in pyrites. This feature appears at the same horizon in Knar Burn farther north (Sheet 18). Beds above the Little Limestone are well exposed at the head of Croglin Water (Sheet 24). The Pattinson Sill here extends downwards to within a few feet of the Little Limestone, and the overlying Firestone Sill is comparatively thin.

In Gilderdale the Whin Sill is over 80 ft. in thickness, and in places its central parts are characterised by an exceptionally coarse texture.

A new conception of the structure of the New Red Sandstone Series of the north-western and western parts of the district has been acquired by Mr. Trotter. The main feature is the repetition of the sequence—St. Bees Shales, St. Bees Sandstone, Kirklinton Sandstone and Stanwix Shales—by a fault (the Crosby Fault) trending from the eastern side of Carlisle, by Low Crosby on the Eden, to the River Cambeck east of Walton Moss. Throwing down south-eastward, it has the effect of shifting the outcrops of the beds south-westward upon its north-westward side. The key to this structure is furnished by two sections; the one in the Hether Burn, the other in the Cambeck south-east of the fault.

In the Hether Burn, commencing about 1 mile east of Hethersgill, the St. Bees Shales, resting unconformably upon Carboniferous rocks, are succeeded westwards, and downstream, by St. Bees Sandstone, Kirklinton Sandstone and Stanwix Shales, the base of the latter being exposed near East Cliff where the Hether Burn joins the Lyne. The Carboniferous Rocks (which occur in the above-mentioned triangular area) extend from the Hether Burn apparently to within a quarter of a mile of the Cambeck (i.e. about 2¼ miles east-south-east of Hethersgill) where a section of boulder-clay is composed—matrix and boulders alike—entirely of Carboniferous debris: suggesting that the solid rocks occur *in situ* at this locality but are separated by a fault from the New Red rocks exposed in the Cambeck close at hand.

To the south-east of the fault, in this neighbourhood, the Cambeck flows in Kirklinton Sandstone, which succeeds the St. Bees Sandstone in a westerly direction about half a mile north of Walton, the beds striking against the fault. South-westward the Stanwix Shales apparently occur at High and Low Crosby east-south-east of the fault, being thus separated from the main outcrop north of Carlisle. North-eastward along the Cambeck and one of the tributaries of the Irthing farther east the St. Bees Sandstone is underlain by St. Bees Shales which rest unconformably upon the Lower Carboniferous rocks of the mair area east of Brampton.

Thus the effect of the Crosby Fault is to shift the unconformable junction of the New Red with the Carboniferous rocks about 3

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miles westward. As one approaches Carlisle the throw of the fault is somewhat less.

Whitehaven Sheet

Additional mining information has been collected from this area ; and further points relating to the succession in the Skiddaw Slates have been cleared up by Messrs. Dixon and Hollingworth.

Mr. Dixon has studied a phase of the local glacial retreat near Floutern Tarn north of Ennerdale (Sheet 29) just beyond the eastern margin of the district. Detailed examination of the phenomena occurring farther south has shown that, for a considerable time after the high ground south of Ennerdale was vacated, there still proceeded from the valley a strong flow of ice which united with the southward-moving ice on the lower land west of the hills. Mr. Hollingworth has traced a series of stages in the withdrawal of the ice south of Ennerdale : these, as a group, are of earlier date than the formation of Glacier Lake Ennerdale.

Maryport Sheet

Borings put down for the Birkby Colliery, in the area bounded by the River Ellen and the Maryport and Rosegill Faults, have been examined by Mr. Eastwood. Although the upper part of the Productive Measures has been removed by denudation, the lower coals, including those worked both at the present and old collieries, occur in workable thickness.

Some time was spent by Mr. Eastwood in tracing, eastward from Cockermouth, the basaltic lavas [1] and underlying conglomerate to their termination near Bothel (Sheet 23). These lavas are now definitely considered to be of Carboniferous age. Their occurrence is of extreme interest, as it is accompanied by a series of peculiar coincidences which have conspired hitherto to disguise their true position in the geological sequence ; for example (1) they occur only upon this north-western border of the Lake District ; (2) their horizon is at the very base of the Limestone Series of West Cumberland ; (3) their position, between the top of the Skiddaw Slates and the Limestone Series, is occupied elsewhere on the northern outcrop by the Ordovician Borrowdale lavas, which are here denuded away ; (4) the eastern end of their outcrop is in contact with, and almost in line with, the western end of the outcrop of the Borrowdale lavas, the latter being apparently succeeded by the Carboniferous Limestone with basal conglomerate.

Bernard Smith.

[1] ' Summary of Progress ' for 1926 (*Mem. Geol. Surv*), 1927, p. 53.

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6. NORTHUMBERLAND AND DURHAM DISTRICT

Headquarters: Newcastle-on-Tyne

R. G. CARRUTHERS, District Geologist.
G. A. BURNETT, B.Sc.
A. FOWLER, M.A., B.Sc. } Geologists.
W. ANDERSON, M.Sc.

IN Northumberland most of the field-work during the past season lay in Sheet 5 (Cheviots), the survey of which was completed. Mr. Burnett revised the ground round the upper reaches of the Coquet, while Mr. Anderson undertook strips along the southern edge of the map round the Border and near Alwinton. Mr. Fowler was largely occupied in going over Coal Measure and Limestone area in Sheet 9, revised by the late Mr. Maden in 1926, and of which a thorough knowledge is required before the memoir can be written.

Silurian.—The patch of greyish-green shales and greywackes, seen along the Border near the southern margin of Sheet 5, is assigned to the 'Upper Silurian' (probably Wenlock) on the published map. As no fossils have yet been discovered in these beds, their precise age still remains doubtful. They are steeply inclined and highly folded. Good exposures are seen round the headwaters of the Coquet above Makendon, but junctions with the overlying volcanics are hidden.

Cheviot Lavas and Granite.—The lavas and ashes along the southern edges of the Cheviot massif are the lowest known on the English side of the Border, but the coarse biotite ashes, with which the eruptive series begins near the 'Silurian' inlier, can only be regarded as a local base, for they contain blocks of a lava no longer seen *in situ*. Fragmentary exposures of conglomerate beneath this series suggest that the earliest Old Red rocks hereabouts are of a sedimentary nature.

The first lavas seen are andesites, notably rich in biotite, and with much ash incorporated in the lower flows; at a higher level, interbedded ash recurs, accompanied by bands of pitchstone, well seen in the Coquet at Blindburn. Andesites of the normal Cheviot type are found above this series; towards Windyhaugh they sometimes show large inclusions of 'Silurian' shale and one or two flows are of a semi-vitreous character.

Around Carshope and Rowhope several 'shatter-belts' have been noted, all trending N.E.; they are up to 75 yards wide, with quartz and calcite cementing the brecciated fragments.

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Granite and Dykes.—As no actual junctions have been found, it is not known whether the southern margin of the Cheviot granite boss shows the close interweaving with the lavas that is seen along the northern edges. It may be noted, however, that the marginal portion to a distance of half a mile from the lavas, is fine-grained and more basic than usual.

Along the Breamish valley, between Linhope and High Bleakhope, many new dykes have been mapped and their radial distribution from the granite boss is now more apparent. A petrographic examination of lavas and granite near their junction round High Bleakhope shows much contamination of both rocks, and recent field-work further down the valley, towards Linhope, suggests that similar phenomena also prevail there. Contact alterations by the dykes are slight, save in a narrow strip of lavas separating two large intrusions at the mouth of the Linhope Burn.

Cementstone Group.—The conglomerate outlier of Windy Gyle, seen well within the lava massif, on the Border, is comparable with the Roddam Dene Conglomerates near Wooler, and as such, should be regarded as a local Carboniferous basement bed. The Cementstone rocks seen along the southern fringe of the lavas are, on the other hand, of normal type. Notwithstanding their pronounced overlap on to older rocks, extending even to the 'Silurian,' only a few feet of the very lowest beds show any traces of conglomerate. On the S. bank of the Coquet, below Alwinton there is a notable cliff section of horizontal Cementstone strata quite 150 ft. high.

Bernician.—The presence of Scremerston measures south of the Simonside Fells has been confirmed by the discovery of a rich entomostracan shale in the stream 700 yds. E. of Selby's Cove. In the Limestone Group new drifts have lately been driven in the coal under the Great Limestone at Wards Hill, 3½ m. S.S.E. from Rothbury: the seam here is thicker than usual, averaging 31 inches, with a roof of hard limy shale rich in marine fossils. Small marine fossils have also been noted above the Chirm seam. In the Stanton district a good outcrop of the Parrot Coal (at one time much wrought hereabouts) have been noted on the left bank of the Font, S.W. of Maiden Hall: it was 29 inches thick, with several thin seams of parrot interleaved.

Coal Measures.—Mr. Fowler reports that mining operations have been resumed S. of Pegswood Moor, and several drifts opened up along the How Burn. The Little and the Old Man coals are being wrought here: they are only 6 ft. apart, and are low in the series, being about 20 fathoms above the Bessie Grey or Brockwell Coal. A *Carbonicola* band, 65 fathoms above the Yard Coal, has been noted on the coast near Cresswell Farm 500 yds. S.W. of Snab Point: this had previously been found in neighbouring borings.

Much new mining information has been collected in the areas N. of Morpeth, and is now being utilised to complete the field evidence previously obtained.

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Glacial.—There is a thin but widespread covering of purplish boulder-clay south of the Cheviot, derived from the underlying lavas: occasionally the colour changes to bluish-grey owing to a local predominance of 'Silurian' material. Mr. J. A. Smythe [1] had reason to believe that at the maximum period of glaciation the Cheviot ice-sheet was over-ridden and pushed back into the hills by the Western ice. Confirmation of this is seen, along the edge of the lava area, in the valley half a mile below Hazeltonrig, where 25 ft. of grey boulder-clay, packed with Cementstone debris, covers the purplish-red Cheviot clay quite distinctly. 'Retreat phenomena,' attending the final phases of glaciation, are not common well within the Cheviot hill-group, but are very evident on the lower ground around Hazeltonrig. The southern spur of Northfieldhead Hill is crossed by a descending series of small notches, 15 in all, while there are still more on Harden Hill and Ewe Hill, ranging from 5 to 40 ft. in depth.[2] The most striking of all is fully a mile long, and at its maximum is about 100 ft. deep; this channel starts on the hillside S. of Hazeltonrig, and, running N.E. crosses the Shartley Burn almost at right angles. All these channels must have been due to the presence of stagnant 'Western ice' over the lower ground, at a time when the smaller Cheviot sheet had disappeared.

R. G. CARRUTHERS.

[1] *Trans. Nat. Hist. Soc. Northum. and Durham*, New Series, vol. IV, p. 116, 1909–1915.
[2] First described by Smythe *loc. cit.*, pp. 108-109, Photos. 6 and 7.

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(B)—SCOTLAND

1. AYRSHIRE, DUMBARTONSHIRE AND STIRLINGSHIRE

E. B. BAILEY, M.C., B.A., District Geologist.
V. A. EYLES, B.Sc.
J. B. SIMPSON, B.Sc.
A. G. MACGREGOR, M.C., B.Sc. } Geologists.

FIELD-WORK was carried out by this unit along the borders of one-inch Sheets 8 (Carrick) and 14 (Ayr), and in one-inch Sheet 30 (Glasgow and Greenock).

AYRSHIRE

Messrs. Eyles and MacGregor revised the Old Red Sandstone outcrops that occur north of the head of the Stinchar valley, and Mr. J. E. Richey spent some time re-examining the Ordovician-Silurian areas on the margins of the Dailly coalfield.

Ordovician-Silurian.—In the Ordovician-Silurian inlier north-east of Girvan graptolites have been collected by Mr. Eckford and determined by Dr. Gertrude Elles which extend in certain particulars the work of Macconochie during the revision of the Southern Uplands. Mr. Eckford's examination was carried out in conjunction with Mr. Richey, who furnishes the following account.

Near the south-west end of the Ordovician-Silurian inlier, westwards of Trochraigue mansion-house, a thick conglomerate considered to be the Bennan Conglomerate occurs in a broad outcrop upwards of 600 yds. in width. It apparently succeeds shales exposed in a stream southwards of the mansion-house from which Macconochie collected a fauna similar to that of the Craighead (Stinchar) Limestone.[1] In an old quarry north-west of the mansion-house, from shales immediately overlying the conglomerate and lithologically resembling its matrix, Mr. Eckford has found *Dicellograptus morrisi*, which Dr. Elles[2] assigns to the Lower Hartfell (Lower Caradoc). The shales probably correspond to the Ardwell Group of Lapworth.

North of Trochraigue mansion-house, from grey shales included in a tumultuous mass of brecciated shales. Macconochie collected graptolites indicating perhaps a slightly lower horizon. These breccias have till now been taken to be the north-easterly continuation of the conglomerate.[3] Locally, however, they are traversed

[1] Peach, B. N. and J. Horne, 'The Silurian Rocks of Britain, Vol. I, Scotland' (*Mem. Geol. Surv.*), 1899, p. 505.
[2] 'Monograph of British Graptolites,' pt. x., 1914, p. 518.
[3] *Op. cit.*, p. 505.

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by abundant pink albite-quartz-veins (26303), and are also bleached and evidently contact-altered. It is noteworthy also that the breccias contain isolated pebbles of chert where they adjoin the conglomerate outcrop, from which the pebbles were presumably derived. The breccias are now concluded to lie within a volcanic vent or else to be the brecciated roof of an intrusion, and seem assignable to no earlier igneous period than that of the Lower Old Red Sandstone. They are seen to extend from a point immediately north of the old quarry referred to above for 350 yds. to the east-north-east.

A new graptolite locality has been found north of the Craighead Limestone Quarry. Grey shales associated with grey flags are exposed in a stream north-east of the road which skirts the quarry on its north-east side, and 400 yds. north-west of Craighead farm-house. They have yielded *Climacograptus antiquus*, *C. lineatus* and *Amplexograptus perexcavatus*, and are assigned by Dr. Elles to the Upper Llandeilo, either the base of the *Climacograptus peltifer* Zone or the top of the *Nematograptus gracilis* Zone. These shales therefore closely approximate in stratigraphical position to the Craighead (Stinchar) Limestone, which in the field they apparently overlie. Farther to the east-north-east, in a stream south-east of Farden and a quarter of a mile north-east of Glenlochrie, a faulted exposure of pale ochreous-weathering shales has yielded *Monograptus triangulatus* among other graptolites. The shales therefore belong to the *Monograptus gregarius* Zone and are without doubt the Glenshalloch Shales reappearing along the faulted south-east limb of the Craighead-Mulloch Hill anticline. Around the north-easterly nose of this anticline, 2 miles farther to the north-east, the main outcrop of these pale ochreous shales was mapped in the first instance by Lapworth. *Monograptus triangulatus* has not hitherto been recorded from the Glenshalloch Shales.[1]

Lower Old Red Sandstone.—The succession on broad lines is sandstone with conglomerate, followed by lavas and intrusions. The lavas are practically all olivine-basalts, often with porphyritic felspar. Acid porphyrite builds big irregular sills or laccoliths at Garleffin Fell, Lennie and Tairlaw. There are also important sills of dolerite, some of them quartz-bearing. Mr. MacGregor reports that an intrusive complex of the suite, at the Fore Burn, consists of diorite, plagiophyre and acid porphyrite, locally extremely rich in dark-bluish tourmaline. The country-rock, sediment and lava, is much altered, with the production of epidote in the basalts and some tourmaline. In the Fore Burn two narrow tourmaline-sulphide veins were found. Specimens examined by Messrs. Sutcliffe and Hallimond contain pyrites, mispickel, and possibly chalcopyrite, with traces of topaz and cassiterite; the percentage of tin, however, is less than 0.0001.

Upper Old Red Sandstone.—Mr. Eyles has found a small

[1] *Op. cit.*, p. 533.

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hitherto undetected outcrop of Upper Old Red Sandstone, including cornstone, half a mile east by south of the Pilot and immediately east of an old coach-road. It is faulted against rocks of Lower Old Red Sandstone age at the only exposed contact.

Dumbarton and Stirling

North of the Clyde Mr. Simpson commenced work at Drymen, and has surveyed a tract of country south of this locality and west of the River Endrick and Blane Water, occupied by Lower and Upper Old Red Sandstones and lavas of Calciferous Sandstone age.

Lower Old Red Sandstone.—Rocks of this age are exposed in the River Endrick at Gartness. They consist of brown and purplish-brown sandstones often with pebbles of andesite lava, and thinner beds of brown marl in which plant-impressions are not uncommon, though usually not sufficiently good to permit of identification.

Upper Old Red Sandstone.—Numerous excellent sections of this formation are exposed in the streams that rise on the northern slopes of the Kilpatrick Hills and drain into the Endrick.

Lithologically the Lower and Upper Old Red Sandstone strata are quite distinct. In its lower horizons the Upper Old Red Sandstone comprises false-bedded brick-red or orange-red strata, somewhat reminiscent of the New Red Sandstone rocks of Mauchline and elsewhere, and the resemblance is heightened by the presence of a certain number of distinctly wind-rounded grains that hint at continental if not desert conditions. Towards the top of the group the red colour gives place to yellow and cornstones appear.

Igneous.—In the Kilpatrick Hills a small area of volcanic rocks has been surveyed west of Auchineden Hill. These are for the most part basalt lavas of microporphyritic (Jedburgh) type.

The base of the group, as at present drawn, runs along the south-west edge of the large intrusion of Jedburgh basalt, lettered F on the one-inch map (Sheet 30), south of Knockvadie. Lava-flows and bedded ash have been proved to occur below this mass and to rest on sandstones of Upper Old Red type without the intervention of Cementstone strata.

Glacial.—North of the Clyde, in the original survey of the Drymen district by Jack,[1] it was noted that the boulder-clay was charged with marine shells of recent types. This boulder-clay he considered to be the ground moraine of a glacier that swept out marine deposits from the Loch Lomond basin.

Resting on the boulder-clay between Drymen and Killearn is a considerable area of sands and gravels in which, also, shells were noted, often rolled and waterworn. Jack was inclined to interpret the shell-bearing gravel as a consequence of a further submergence below sea-level, but it was pointed out by J. Geikie[2] that the

[1] Jack, R. L., 'Notes on a Till or Boulder Clay with Broken Shells in the Lower Valley of the River Endrick near Loch Lomond, and its Relation to certain other Glacial Deposits,' *Trans. Geol. Soc. Glasg.*, vol. v., part 1, 1875, pp. 5–25.

[2] Geikie, J., 'Great Ice Age,' 1894, p. 281.

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shells could easily be derived from the older shelly boulder-clay, and that their water-worn condition supported this contention. On his view the sands and gravels were a fresh-water lake deposit.

In the memoir on the Glasgow district, Bailey [1] drew attention to a channel near Balfron eroded by the eastwardly escaping waters of Geikie's lake, and interpreted this lake as temporarily impounded by retreating Loch Lomond ice.

In the course of the year's work further evidence bearing on this problem has been collected. A widespread expanse of sand and gravel extends south from Finnich Drummond to High Finnich, and terminates in a well-marked moraine ridge, which, so far, has been traced 2 miles westwards from near the volcanic neck of Meikle Caldon to Cameron Muir. It is known to extend still further. It lobes outwards to the south and there is no doubt that it has been deposited by ice from the north.

The shelly boulder-clay is found to extend over a much wider area than was indicated in the original map, and in particular is proved to exist close to the moraine on its northern side at a height of 300 ft. on the banks of Finnich Glen west of Auchineck House. So far no shells have been noted in the boulder-clay south of the moraine.

It is believed that we are here dealing with the frontal moraine of the Loch Lomond glacier that deposited the shelly boulder-clay.

E. B. BAILEY.

[1] Bailey, E. B., 'The Geology of the Glasgow District' (*Mem. Geol. Surv.*), 2nd Ed., 1925, p. 230.

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2. PEEBLESSHIRE AND MIDLOTHIAN

J. E. Richey, M.C., B.A., District Geologist.
H. H. Read, D.Sc., A.R.C.Sc., Senior Geologist.
J. Phemister, M.A., B.Sc., Geologist.

ONLY a small area in one-inch Sheet 24 was mapped during the past year owing to the surveyors concerned being engaged in memoir writing and other work, and about 35 square miles of post-Silurian rocks have still to be revised before the Sheet can be colour-printed.

Carboniferous Limestone Series.—Certain advances have been made in the detailed stratigraphy of the lower part of the Carboniferous Limestone Series in the Carlops-Leadburn district, which forms the southern portion of the Midlothian coalfield. The Lower Limestone sequence of the Carlops area was dealt with in a recent *Summary of Progress*,[1] and the individual limestones were correlated with those in the well-known succession established in the Bilston Burn to the north. Near Leadburn, 4¾ miles east of Carlops, exposures are few, but the continuation of the various limestones into this area is proved by a diamond bore at Hall Farm, which was examined by the late Dr. C. T. Clough. In this boring the succession is as follows :—

	Ft.	In.
Harelaw Limestone	1	7
Strata including two thin coals	32	—
Bilston Burn Limestone	27	—
Strata	20	—
(? Upper) Vexhim Limestone	—	9
Strata	41	
North Greens Limestone	64	—
Strata	39	—
Gilmerton Limestone — Limy shale	18	—
Gilmerton Limestone — Limestone	35	—
Strata	10	—
Limestone	4	6
Strata	38	—
First Abden Limestone — Limestone	1	6
First Abden Limestone — Limy shale	3	—
Strata	11	—
Cephalopod Limestone, and limy shale	12	—

In this succession the Lower Vexhim Limestone is apparently unrepresented, the strata between the North Greens Limestone and the limestone correlated with the Upper Vexhim being mainly sandstone. A few miles east of Leadburn, in Sheet 24, the Lower Limestones occur near Hillhead and Side in outcrops which extend

[1] Richey, J. E., *in* 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, pp. 110–112.

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northwards into Sheet 32, along the eastern margin of the Midlothian Basin. The sequence of limestones has been worked out from exposures at North Middleton, Esperston, and Rosebery Reservoir (South Esk),[1] and resembles that proved at Leadburn sufficiently closely to enable the following correlations to be made :—

Hall Farm Bore, Leadburn (one-inch Sheet 24)	*Esperston-Middleton District* (one-inch Sheet 32)
Harelaw Limestone	Thin limestone, South Esk
Bilston Burn Limestone	Thick Esperston Limestone
(? Upper) Vexhim Limestone	Thin limestone with Cauda-galli
North Greens Limestone	Thick limestone of Middleton Quarries
Gilmerton Limestone	Thick limestone of quarry south-west of Wester Middleton
? First Abden Limestone	Thin limestone in burn at North Middleton

The limestones of the Esperston-Middleton succession have already been recorded in the Edinburgh District Memoir,[2] with the exception of the thin post at the base. This was recently identified in the Middleton North Burn, a little way downstream from the bridge at North Middleton, where it outcrops from beneath sandstone and shales containing ironstone nodules. A gap of several yards separates these strata from an overlying thick limestone resting on a coal-seam. This thick limestone represents either the Gilmerton Limestone or the North Greens (Middleton Quarry) Limestone ; if the latter, the Gilmerton Limestone must be cut out of the section by a fault.

J. E. RICHEY.

[1] Hinxman, L. W., and C. B. Crampton, *in* ' The Geology of the Neighbourhood of Edinburgh ' (*Mem. Geol. Surv.*), 1910, pp. 186–190.
[2] *Loc. cit.*

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3. FIFE AND KINROSS

C. H. DINHAM, B.A., District Geologist.
D. HALDANE, B.Sc.
J. K. ALLAN, M.A., B.Sc.
J. KNOX, B.Sc.
} Geologists.

DURING the past year, owing to exigencies of other work, Mr. Allan alone of this unit has been continuously engaged in the resurvey of the Fifeshire coalfield, Mr. Knox joining him in field-work for a few weeks in the autumn. The whole coal-bearing area, from the western boundary of Fife to the great dislocation which truncates the Dysart coalfield near Markinch, has now been revised, and only a small tract of Calciferous lavas and sediments still remains to be mapped. With the generous assistance of the various colliery companies, much further mining information has been secured by all members of the unit; some important deep bores in progress have also been examined.

Limestone Coal Group.—On the north shore of Loch Fitty, about 130 yds. east from the western boat-house, a low cliff section reveals several feet of shales (fakes and blaes) containing lamellibranchs and other marine fossils. As a result of Mr. Allan's work it may now be safely assumed that we have here an exposure—at present the only known natural exposure—of the shelly marine horizon which rests on the Stink or Sulphur Coal of the Dunfermline district and on the Smithy Coal of Bo'ness.[1] The same strata have been found to be fossiliferous in cross-cut mines and in bores; the horizon is probably persistent through western and west-central Fife, but it is not as yet possible to affirm its presence outside this tract. In this connection it should be remarked that in the Valleyfield area, where this group reaches its maximum thickness, one or two other neighbouring 'shelly' horizons are recorded, both above and below the marine band here considered; generally these contain nothing more marine than *Lingula*, but they may be expected locally to yield other brachiopods or even encrinites, as at Carriden in the Bo'ness field.[2] One of the *Lingula* bands lies a few feet above the Dunfermline Splint Coal, and may possibly correspond to that found on top of the Milton Grove or Lower Knott Coal in the Stirling district.

A further step in correlation between Fife and the Central

[1] *Cf.* Cadell, H. M., 'A Volcano in the Bathgate Coalfield of West Lothian,' *Trans. Inst. Min. Eng.*, vol. lxv, pt. 5, 1923, p. 257.
[2] 'Summary of Progress' for 1923 (*Mem. Geol. Surv.*), 1924, p. 118, fig. 11, col. (1).

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Coalfield has resulted during the year from the examination of bore cores by Mr. Haldane and Mr. Manson. The marine band in the 'Black Metals' has in recent years been traced all over the Central Coalfield[1] from Glasgow and Lesmahagow to the vicinity of Stirling; the Kilsyth Coking Coal (equivalent to the Milton Grove just mentioned) and a few other associated but rarely workable seams lie below it, but most of the valuable coals of the group are found above it. It has not hitherto been traced on the north side of the Forth, but we now know that it is to be expected at least as far east as Culross and perhaps Saline. In this part of Fifeshire, below the Main or Lower Four Foot of Comrie (Jewel or Swallowdrum of Valleyfield and Lochgelly Splint of Blairhall), lies a zone, about 250 ft. thick, which is generally barren of even the thinnest coal seam, but commonly contains two fairly thick horizons of shales (blaes) and ironstone ribs, alternating with thick sandstones. The upper and thinner of these blaes beds has yielded Productids and other marine fossils, the lower mostly *Lingula* and entomostraca, and there is no doubt that together they represent the 'Black Metals' of the west. It follows that the Glassee, Mynheer, Five Foot, and Splint coals of Dunfermline and eastern Fife form a group that is represented in the Central Coalfield only by the Kilsyth Coking Coal and adjacent seams—a conclusion long previously suspected, but now receiving important confirmation. There appears to be some indication that east of the Culross and Saline area this marine horizon may cease to carry fossils, but it is difficult to be certain until the Survey have the opportunity of examining a section through these strata in Central Fife. Whether, in the type area at Lochgelly, the Lochgelly Splint and Parrot Coals lie above or below this horizon has not been definitely proved, but from the evidence available it is believed that they overlie it.

In the ground between Dunfermline and Blairenbathie Mr. Allan found that intense N.N.E. folding, with powerful cross-faulting, is still the dominant structure. Correlation of individual coals of the thick but variable Jersey and Fourteen Foot groups is still a matter of the greatest difficulty, and is further complicated by the intrusive dolerite sill occurring about this level. This sill thickens considerably to the north, and Mr. Allan finds reason to suppose that its source lies in that direction, towards the continuation of the great Ochil Fault, which in some other parts of its course appears to have acted as a conduit for the dolerite magma.[2]

Upper Limestone Group.—The Index Limestone at the base of this group has been further traced in the ground revised by Mr. Allan, but no additional light has been shed on the presence or position of the higher limestones.

In this connection it is worthy of remark that the Lyoncross

[1] *Ibid.*, pp. 110–12.
[2] Haldane, D., in 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, Appendix VIII.

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Limestone of the Central Coalfield—the thinnest limestone of the group—is not known to extend east of Blairhall and Comrie, and even there it is developed merely as a thin bed of blaes, with scarce marine fossils: in eastern Fife it is perhaps entirely unrepresented. It can, however, now be shown that its position lies a few fathoms above the Crumpy or Upper Coal of Inzievar, and that this seam is thus equivalent to the Quarry Coal of Plean and Denny (Stirlingshire), while Cadell's Parrot of the former area is not far from the position of the Chapelgreen Coal of Kilsyth.

A special study was made by Mr. Allan of the region west of Kinglassie, resulting in considerable alterations to the mapping of the Upper Limestone Group. The limestone hitherto correlated with the Castlecary is now regarded as the Calmy, and the upper limit of the group is drawn about 30 fms. higher.

Millstone Grit and Coal Measures.—In the same area Mr. Allan found that the Millstone Grit cannot exceed 65 fms. in thickness and is more probably only 35 fms. It is succeeded by Coal Measures, of which about 150 fms. have survived denudation. The lowest coal, about 15 ft. below the Westfield Shale, marks the beginning of an extraordinary deposition of organic matter, attaining at the maximum a thickness of no less than 130 ft. in a total of 200 ft. of strata. No correlation of this remarkable sequence with the standard sections of Dysart and Leven is yet possible.

In the last-mentioned field, Mr. Knox has found that the normal easterly dip is broken by two major folds, with axes running N. and S.—a syncline in the west and an anticline in the east—which extend northwards to the great boundary fault, but pitch out southwards before reaching the coast, where the dip is constantly to E. We seem in these to have reached the eastern limit of that belt of repeated N.N.E.—S.S.W. folding whose other border lies near Culross, Blairhall, and Saline, 18 miles to westward.

C. H. DINHAM.

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4. NORTH HIGHLANDS

J. E. Richey, M.C., B.A., District Geologist.
H. H. Read, D.Sc., A.R.C.Sc., Senior Geologist.

THE western fourth of one-inch Sheet 109 (Achintoul), comprising parts of the deer forests of Ben Armine, Loch Choire, Borrobol and Badanloch, has been examined by Dr. H. H. Read. This area forms the eastward continuation of the Ben Klibreck district, in one-inch Sheet 108, described in last year's *Summary of Progress* (pp. 64-6). It was originally mapped mostly by the late Dr. C. B. Crampton in 1909-1913; a small area in Ben Armine forest was examined by Mr. M. Macgregor in 1911-1913, whilst in 1891-4 Dr. E. Greenly had surveyed the district east of Strath Naver. Its re-examination by Dr. Read was undertaken for three main reasons; the first, to extend eastwards the geological boundaries established in 1926 in Sheet 108, the second, to enquire into the significance of the "gneisses of Lewisian type" described chiefly by Dr. Crampton, and the third, to gather material for the Memoir on Sheets 108 and 109, now in preparation. Dr. Read gives the main conclusions resulting from his re-examination in the following report.

Moine Series and Granite Complex.—The range of the two Ben Armines, consisting of Creag a' Choire Ghlais and Creag Mhòr, affords on the east a series of magnificent crag-sections overlooking the peaty waste of Borrobol Forest. At the base of the crags is exposed a group of siliceous granulites and semipelitic schists with occasional lenses of hornblende-schist; threads and sheets of granite and pegmatitic material are not abundant at the lower levels but increase in size and number higher up. The group passes at a gentle angle beneath an intimate mixture of pelitic schists and granitic injections, in which the igneous component is dominant. At or about the junction of the pelitic country-rock above and the siliceous country-rock below, there occurs a persistent sheet, or group of sheets, of granite. This type of section continues from the Bealach na Muic at the south end of the Ben Armine range to Coire na Saidhe Duibhe at the north end, and can be followed from the latter locality north-westwards and then westwards into the Loch Coire hollow.

Topographically and geologically, Ben Armine is a repetition of Ben Klibreck. The lower siliceous zone of Ben Armine produces vertically-jointed precipitous crags like those formed by similar rocks at the Pap on Klibreck. Above this zone, at both Ben Armine

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and Ben Klibreck, appear jagged irregular crags of a complex of granitic material and pelitic schists. The geological sections of the two mountains are similar not only in the nature and the relations of the country-rocks, but in the character, amount and distribution of the injected igneous material. But the Ben Klibreck section faces west, the Ben Armine section east ; hence the conclusion that the pelitic schists of the Ben Armine, Loch Coire and Ben Klibreck area lie in some form of outlier or infold above the siliceous group seems a reasonable one. The margin of this outlier between Ben Armine and Ben Klibreck has been traced on the north side ; on the south side its course is more conjectural, being largely obscured by the high-level peat south of Loch Coire.

The siliceous rocks of the lower zone of Ben Armine and Loch Coire were styled " gneisses of Lewisian type " or even " Lewisian rocks " in the *Summaries of Progress* for the years 1910-1913. They were considered to be succeeded, possibly unconformably, by the upper pelitic zone which belonged to the Moine Series. The subject cannot be discussed adequately here, but there is no doubt that the siliceous and semipelitic rocks in question are typical siliceous granulites and semipelitic schists of the Moine Series and differ in no respects from undoubted Moine rocks occurring in the corresponding position on Ben Klibreck. With regard to the nature of the junction-plane between these " rocks of Lewisian type " and the overlying pelitic Moine schists, it may be stated that the detection of a plane of unconformity amid the igneous injections and complexes of the Ben Armine range is a problem of great difficulty. No such plane, however, is suspected at the corresponding position on Ben Klibreck.

Northwards from the localities just discussed, and eastwards towards Kinbrace, and the Griams, the rocks are complexes of siliceous, semipelitic and pelitic members of the Moine Series with varying amounts of granitic material. Here again, " rocks of Lewisian type " or of " Lewisian age " were considered to occur by Dr. Crampton (*Summary of Progress* for 1909, p. 39). In Dr. Read's opinion, however, all the country-rocks of these districts belong to types well-known in the Moine Series.

J. E. RICHEY.

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5. ORKNEY ISLANDS

J. E. RICHEY, M.C., B.A., District Geologist.
J. KNOX, B.Sc.
J. V. STEPHENS, B.Sc., B.ENG.
WILFRID EDWARDS, M.A.
R. C. B. JONES, M.C., M.Sc. } Geologists.

THE survey of Orkney was begun during the past summer by Mr. Knox from the Scottish Staff together with Messrs. Stephens, Edwards and Jones from the Yorkshire and Lancashire units. On the Orkney mainland Mr. Knox and Mr. Stephens have surveyed areas in the vicinity of Kirkwall and Stromness respectively. Mr. Edwards has mapped South Ronaldshay, Burray and the smaller islands between South Ronaldshay and Caithness. Mr. Jones has completed certain of the northern islands including Sanday, Eday, and North Ronaldshay.

Granitic Complex of Stromness.—These rocks have long been known to underlie the Stromness Beds, the lowest subdivision of the Orcadian Middle Old Red Sandstone. Mr. Stephens' detailed mapping shows that the granite outcrop extending north-north-west through Stromness is not continuous, but consists of a number of small outcrops separated from one another by the overlying Stromness flagstones.[1] The old rocks are composed of a complex of granite and sedimentary schists, the latter being mainly similar to the Moine Schists of the North Highlands. The schists form outcrops of some extent which are fairly free from granite intrusions, and also occur in patchy fashion enclosed in or copiously injected by the granite. The complex exactly resembles in the field the extensive granite and Moine Schist complex of Sutherlandshire.[2]

Middle Old Red Sandstone.—The sequence and classification of these strata as described by Drs. Peach and Horne [3] and by Sir John Flett [4] form the basis of the work of the present survey. Additional information has so far been collected more especially with regard to the Eday or John o' Groats sandstones, which form

[1] *Cf.* A. G. Steavenson, 'Some Geological Notes on Three Districts of Northern Scotland, *Trans. Geol. Soc. Glasg.*, vol, xviii, pt. i, 1928, p. 216.

[2] Horne, J., and E. Greenly, 'On Foliated Granites and their Relations to the Crystalline Schists in Eastern Sutherlandshire,' *Quart. Journ. Geol. Soc.*, vol. lii, 1896, pp. 633–648; H. H. Read *in* 'The Geology of the Country around Golspie,' Explanation of Sheet 103 (*Mem. Geol. Surv.*), 1925, pp. 21–40; *and in* 'The Geology of Strath Oykell and Lower Loch Shin,' Explanation of Sheet 102 (*Mem. Geol. Surv.*), 1926, pp. 148–152.

[3] Peach, B. N., and J. Horne, 'The Old Red Sandstone of Orkney,' *Proc. Roy. Phys. Soc. Edin.*, vol. v, 1880, pp. 329-342.

[4] Flett, Sir J. S., 'The Old Red Sandstone of the Orkneys,' *Trans. Roy. Soc. Edin.*, vol. xxxix, pt. ii, 1898, pp. 383-424.

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the upper portion of the Middle Old Red Sandstone of Orkney and Caithness. These beds have been examined chiefly in Eday and Sanday and in South Ronaldshay and Burray. In both of these areas a transition group between the underlying Rousay flags and the Eday sandstones has been mapped by Messrs. Jones and Edwards. This group consists of thin, siliceous sandstones interbedded with the Rousay flags for a short distance below the first thick sandstone met with. The base of the latter is taken as the base of the Eday Beds proper. Some 300-600 ft. above this base in Sanday and Eday a group of flags is interbedded in the sandstones from which, north of Strang Quay in Sanday, *Tristichopterus alatus* has been collected. In South Ronaldshay, flags corresponding closely in stratigraphical position to the above-mentioned group have also yielded *Tristichopterus alatus* together with *Pentlandia* (*Dipterus*) *macropterus* (p.75). These records of *T. alatus* supplement Sir John Flett's [1] original discoveries of this species in Orkney from flags interbedded with the Eday sandstones of Shapinshay and the eastern Mainland.

The thicknesses of the Eday Beds in Eday have been estimated by Mr. Jones. He finds that the Lower Eday Beds (excluding the transition group), which consist mainly of pebbly yellow and red sandstone, are 1,700-2,000 ft. thick, while of the Upper Eday Beds, composed of red marls and fine-grained sandstones usually red, 2,800 ft. are seen. In South Ronaldshay the sequence is repeatedly interrupted by faults, and estimates of thickness made by Mr. Edwards are consequently only approximate. In the area including the northern half of this island and Burray the Lower Eday Beds are about 1,400-2,000 ft. thick, and the Upper Eday Beds (top not seen) about 1,600 ft.

Faults.—While there is no doubt that the majority of the faults traversing the Orkney Old Red Sandstone are normal, a good example of a reversed fault is noteworthy. This fracture extends N.-S. adjacent to the eastern shore of Scapa Bay, where it has been mapped by Mr. Knox. It is admirably displayed in a cliff opposite Gaitnip, heading to the east at 55°, and bringing up the Rousay flags to the east against the Eday Beds to the west.

Pleistocene.—Striae and foreign boulders in the boulder-clay have been noted which confirm Drs. Peach and Hornes' [2] well-established conclusion regarding the passage of an ice-sheet northwestwards over the Orkneys bearing Scottish mainland boulders.

J. E. RICHEY.

[1] Flett, Sir. J. S., *op.cit.*, pp. 385 and 412-414.

[2] Peach, B. N., and J. Horne, 'The Glaciation of the Orkney Islands,' *Quart. Journ. Geol. Soc.*, vol. xxxvi, 1880, pp. 648-663; 'On the Occurrence of Shelly Boulder Clay in North Ronaldshay, Orkney,' *Trans. Edin. Geol. Soc.*, vol. vi, 1893, pp. 309-313.

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III. SECTIONAL REPORTS

1.—PALAEONTOLOGICAL DEPARTMENT

In London

F. L. KITCHIN, Sc.D., PH.D., Palaeontologist (District Geologist).
J. PRINGLE, Assistant-Palaeontologist
C. P. CHATWIN, M.Sc., Assistant-Palaeontologist } (Senior Geologists).

In Edinburgh

G. W. LEE, D.Sc., Senior Geologist.

1. ENGLAND AND WALES

A CROWDED programme of work, chiefly connected with the preparation of memoirs, has been carried out in the department, and the results will eventually appear in these publications. In the course of this work there has emerged little of outstanding interest to which attention should here be drawn.

Practically no palaeontological work has been done in the Coalbrookdale coalfield since the publication of Prestwich's memoir in 1845. For the purpose of the forthcoming memoir on the Wolverhampton sheet Mr. Pringle revised the fossils in the Museum from the Coal Measures of that district, particularly those from the well known marine horizon, the Pennystone Ironstone. Species of *Spirifer* from this horizon, recognized by Mr. Pringle as undescribed forms, have been investigated by Mr. T. N. George, whose account of them is now awaiting publication. Mr. Pringle and Dr. R. Crookall visited sections in Coalbrookdale and contributed a joint account of the palaeontology of the Coal Measures, which will appear in the memoir.

Mr. Pringle has paid a further visit to the locality near Gilsland (North Cumberland) which yielded the new brachiopods mentioned in the previous year's *Summary of Progress* (p. 68). He secured an exceptionally fine example of *Crossochorda tuberculata* Williamson from the same beds (S_2) in the Limestone Series. This has now been placed in the Museum collection.

During his field-work in connexion with the revision of the Merthyr Tydfil sheet, Mr. Pringle examined fossils from the Brass Vein, and in the material studied he recognized a new species of *Belinurus*. He hopes to obtain more material and to publish a description of this form. During an unofficial visit to the sandpits at Billington Crossing, Leighton Buzzard, he secured an example of a new species of *Cleoniceras* from the *regularis* subzone of the Albian. This specimen has been presented to the Museum and has been figured by Dr. Spath as *Cleoniceras morgani*, in his monograph on the 'Ammonoidea of the Gault.' This makes an interesting addition to the known species of the *regularis* subzone, which has so little representation in this country.

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Further material has been obtained from the ironsands yielding late Pliocene fossils on Netley Heath. From the abraded condition of 45 lumps of fossiliferous ironsand obtained by Mr. F. H. Edmunds, it seems evident that these occur as boulders in a gravel. In last year's *Summary of Progress* Mr. Chatwin commented on the frequent occurrence in the ironsand of *Corbulomya complanata* Auctorum. This is confirmed by the finding of 8 examples of this shell in two lumps of ironstone presented during the year by Mr. W. Wright.

Mr. Chatwin has revised a number of cases of Chalk fossils in the Museum and has arranged a new exhibit showing the chief faunal characters of the successive zones of the Chalk. The plan adopted will meet the demand for a narrower subdivision of the strata under each formation in the exhibited collection; and it is hoped to extend this method of treatment to other parts of the stratigraphical series of fossils shown in the Museum.

The following specimens in the Museum have been figured, described or mentioned in publications :—

IN THE PALAEONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1925 (Published 1927).

A Monograph of the British Palaeozoic Asterozoa. (Part vii). By DR. W. K. SPENCER, M.A., F.G.S.

Stenaster obtusus (*Forbes*), pl. xxiii, figs. 8, 9, p. 356.
Onychaster barrisi (*Hall*), pl. xxi, fig. 13; text-figs. 219, 220, p. 340.

A Monograph of the Ammonoidea of the Gault. (Part v). By DR. L. F. SPATH, F.G.S.

Callihoplites *aff.* auritus (*J. Sowerby*), pl. xvii, fig. 1; text-fig. 61, p. 197 (4 specimens).
,, variabilis *Spath*, pl. xviii, fig. 2, p. 202 (2 specimens).
,, horridus *Spath*, pl. xviii, fig. 9; text-figs. 62a, b, p. 200 (2 specimens).
,, formosus *Spath*, pl. xix, figs. 5a, b, p. 196.
,, patella *Spath*, pl. xx, fig. 5, p. 192.
,, strigosus *Spath*, *var.* cristatus *Spath*, text-fig. 59, p. 195.
,, tetragonoides *Spath*, p. 204.
Cleoniceras morgani *Spath*, pl. xvii, fig. 7; pl. xviii, fig. 5.

A Monograph of the Fossil Macrurous Crustacea of England. (Part iv). By MR. H. WOODS, M.A., F.R.S.

Glyphea *cf.* tomesi *H. Woodward*, pl. xiii, figs. 3a, b, p. 49 (2 specimens).
,, cretacea *McCoy*, p. 62.

A Monograph of British Dendroid Graptolites. (Part i). By DR. O. M. B. BULMAN, D.I.C., A.R.C.S., F.G.S.

Dictyonema flabelliforme (*Eichwald*), *var.* sociale (*Salter*), pl. ii, fig. 1; text-fig. 15, p. 26 (2 specimens).

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IN THE PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY OF LONDON, SERIES B, VOLUME CCXVI.

II. *The Corallian Rocks of Oxford, Berks and North Wilts.*
By MR. W. J. ARKELL, B.A., B.Sc., F.G.S.

Cyprina corallina *d'Orbigny*, pl. i, fig. 5.
Terebratula kingsdownensis *Arkell*, p. 175 (8 specimens).

IN THE QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY, VOLUME LXXXIII.

A Revision of the Non-Marine Lamellibranchs of the Coal Measures and a discussion of their Zonal Sequence.
By MR. J. H. DAVIES, F.G.S., AND DR. A. E. TRUEMAN, F.G.S.

Carbonicola sp., pl. xvi, figs. 5a, b, (2 views), p. 245.
Anthracomya (?) sp. nov., pl. xvii, figs. 8a, b, (2 views), p. 245.

A Critical Revision of the Rugosa Corals described by W. Lonsdale in Murchison's 'Silurian System.'
By DR. W. D. LANG, M.A., F.G.S., AND DR STANLEY SMITH, M.A., F.G.S.

Tryplasma flexuosum (*Linnaeus*), pl. xxxiv, figs. 1a—c, p. 464; text-figs. 11, 12, p. 461.
Arachnophyllum murchisoni (*Edwards and Haime*), pl. xxxiv, figs. 2, 3, p. 467.
,, diffluens (*Edwards and Haime*), pl. xxxiv, fig. 4, p. 468.
Patrophontes truncatus (*Linnaeus*), pl. xxxv, fig. 4, p. 474.
Acervularia ananas (*Linnaeus*), *var.* truncata (*Wahlenberg*), pl. xxxv, figs. 6—8, p. 474.
Xylodes pseudodianthus (*Weissermel*), pl. xxxv, fig. 9, p. 475.
Cystiphyllum cylindricum *Lonsdale*, pl. xxxvi, figs. 1—3, p. 477.
,, siluriense *Lonsdale*, p. 476.
Acanthocyclus binus (*Lonsdale*), pl. xxxvii, fig. 5, p. 483.
'Turbinolopsis' elongata *Phillips*, pl. xxxvii, figs. 6, 7, p. 484.
Phaulactis angusta (*Lonsdale*), p. 469 (2 specimens).
Chonophyllum (?) patellatum (*Schlotheim*), p. 482 (3 specimens).
Palaeocyclus porpita (*Linnaeus*), text-fig. 17, p. 486 (3 specimens).

The Occurrence, Structure, and Affinities of Echinocystis and Palaeodiscus.
By PROF. H. L. HAWKINS, D.Sc., F.G.S., AND MISS S. M. HAMPTON, B.Sc.

Echinocystis pomum *Wyville Thomson*, pl. xliv, fig. 1, p. 581 (2 specimens).
Palaeodiscus ferox *Salter*, pl. xliv, fig. 2, p. 588; text-fig. 5, p. 590.

IN THE ANNALS AND MAGAZINE OF NATURAL HISTORY, VOLUME XIX, NINTH SERIES.

Two new Species of Lower Carboniferous Brachiopoda from Northumberland.
By MISS H. M. MUIR-WOOD, M.Sc., F.G.S.

Pustula thomasi *Muir-Wood*, text-figs. 1, 2, p. 288.
Punctospirifer northi *Muir-Wood*, text-figs. 3—6, p. 290.

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IN THE GEOLOGICAL MAGAZINE, VOLUME LXIV.

Bernicia praecursor *gen. & sp. nov., a Lower Carboniferous Freshwater Gasteropod.*
By MR. L. R. COX, M.A., F.G.S.

Bernicia praecursor *Cox*, text-fig. 1, (3 views), p. 327.

IN THE MEMOIRS AND PROCEEDINGS OF THE MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY, VOLUME LXXI.

X.—*New Carboniferous Lamellibranchs and Notes on other Forms.*
By MR. J. WILFRID JACKSON, M.Sc., F.G.S.

Pterinopecten papyraceus (*J. Sowerby*), pl. i, fig. 1 ; pl. ii, fig. 5, p. 96.
,, elegans *J. W. Jackson*, pl. i, fig. 2 ; pl. ii, fig. 4, p. 103.
,, speciosum *J. W. Jackson*, pl. i, figs. 3, 4 ; pl. ii, fig. 3, p.105.
,, rhythmicus *J. W. Jackson*, pl. ii, fig. 2, p. 107.
Posidonomya insignis *J. W. Jackson*, pl. iii, fig. 3, p. 114 (5 specimens).
,, minor (*Brown*), pl. iii, fig. 7, p. 116.
,, rugata *J. W. Jackson*, pl. iii, figs. 8, 9, p. 117 (3 specimens).
,, multirugata *J. W. Jackson*, pl. iii, figs. 10—12, p.118 (7 specimens).

IN TYPE AMMONITES, VOLUME VI.
By MR. S. S. BUCKMAN, F.G.S.

Vermidactylites vermis (*Simpson*), pl. lxviiiA, figs. 1, 2.
Lunuloceras lonsdalii (*Pratt*), pl. diiA.
Xeinodactylites helianthoides (*Yokoyama*), pl. dcxcix, figs. 1—3.
Dactylioceras annulatum (*J. Sowerby*), pl. dcc, p. 43.
Prionodoceras truculentum *S. Buckman*, pl. dcciv, figs. 1, 1a, 2.
Simplidactylites simplicicosta *S. Buckman*, p. 43 (2 specimens).
Parvidactylites parvus *S. Buckman*, p. 43.

IN TYPE AMMONITES, VOLUME VII.
By MR. S. S. BUCKMAN, F.G.S.

Pseudocadoceras ? laminatum *S. Buckman*, pl. dccxxvii.
,, ? concinnum *S. Buckman*, pl. dccxxxv.
Nodicoeloceras crassoides (*Simpson*), pl. lxxxixA, figs. 1, 2.
,, acanthus (*d' Orbigny*), pl. dccxxixA ; pl. dccxxixB.
Allovirgatites distans (*Neaverson*), pl. dcxxxviiic ; pl. dcxxxviiiD.
Crassicoeloceras pingue *S. Buckman*, pl. dccxxviii, figs. 1, 2.
Lobodactylites lobatum *S. Buckman*, pl. dccxxx, figs. 1, 2.
Orthodactylites nitis *S. Buckman*, pl. dccxxxviii, figs. 1, 2.
Harpoceratoides strangwaysi (*J. Sowerby*), pl. dccxxxix, figs. 1, 2.
Glyptarpites glyptus *S. Buckman*, pl. dccxl, figs. 1—3, p. 9.
Tardarpoceras tardum *S. Buckman*, pl. dccxli, figs. 1—3, p. 9.
Harpoceras concinnum *S. Buckman*, pl. dccxlii, figs. 1, 2.

IN MEMOIRS OF THE GEOLOGICAL SURVEY, ENGLAND.
THE GEOLOGY OF THE ROSSENDALE ANTICLINE.

Chapter IX.—*Palaeontology.*
By MR. W. B. WRIGHT, M.I.M.E., F.G.S.

Reticuloceras reticulatum, *early mut.* γ, *mut. nov.*, pl. vi, figs. 1, 2, 6, p. vii (3 specimens).
Gastrioceras lineatum *Wright*, pl. vi, figs. 3, 4, 8, p. vii (3 specimens).
Gastrioceras ? sigma *Wright*, pl. vi, figs. 5, 7, p. vii (2 specimens).

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2. Scotland

Dr. Lee reports that as most of the Carboniferous materials were obtained from the cores of borings, large suites of well preserved fossils were not available for detailed study. In spite of this limitation, a point of both faunistic and stratigraphical interest has been brought to light, which may prove of use in determining positions within the Millstone Grit of Stirlingshire and Clackmannanshire.

Two borings put down some miles south-west of the Forth, and one south of Dollar, north-east of the Forth, have revealed the presence of a marine band characterized by *Productus carbonarius* de Koninck, *P. cora* d'Orbigny [Tschernyschew] (not of British authors), and a new species of *Productus* with extremely fine striation. That this marine horizon persists over a fairly wide area is shown by the fact that the same forms, among others, were found in a natural section (Rough Cleuch burn) three miles south-east of Dollar. This horizon is considerably higher up in the Millstone Grit sequence than that at the base of the formation from which the late Dr. Wheelton Hind described a lamellibranch-fauna of North American Upper Carboniferous facies.

The Survey is indebted to Mr. Wallace Thorneycroft, of the Plean and Lochgelly Collieries, for drawing attention to another point of considerable stratigraphical value. He sent for examination a suite of fossils obtained from the roof of the 'Coal Stink' of the Mary Pit, Lochgelly, Fife, which proved to be purely marine, with certain elements in common with the marine fauna of the roof of the 'Smithy Coal' of Bo'ness, in Linlithgowshire.

Numerous fossil fishes were obtained from the Old Red Sandstone by the members of the Orkneys unit during the summer of 1927, and the following notes concerning them are supplied by Prof. D. M. S. Watson, F.R.S., who has examined the collection :—

'The materials collected from the Stromness Beds at various localities in the parishes of Stromness and Sandwick give a nearly complete representation of the well known fauna, which occurs in this area and also at Achanarras, Caithness, and in the Moray Firth nodule localities.

'The commonest fish are those which I have referred to "*Osteolepis macrolepidota*," using this specific name in the sense of Traquair and Smith Woodward. It is perfectly clear that even amongst the present specimens two or three species are included under this head; none of these is identical with the form which is abundant at Tynet Burn, Banffshire, nor are any certainly the same as the Gamrie fish. The differences are only recognisable in well preserved specimens which show the structure of the head. I hope to bring together a series of these fish from all the localities in which they occur, and then distribute them amongst a number of species.

'Little of the material from the parish of Kirkwall is specifically determinable and, so far as collecting has been carried out, no

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recognisable specimens of the fish characteristic of the horizon of Thurso have been found to be present.

'There are, however, two specimens of interest from the Rousay Beds of the parish of Kirkwall: No. T.4413[g], the fronto-ethmoidal shield of a large Osteolepid, is certainly undescribed and of unusual structure. No. T.4436[g], from 420 yards E. 8° N. of Inganess Farm, 1½ miles S.E. of Kirkwall, is part of the skeleton of a large Coccostean. It differs from *C. decipiens* most markedly by the absence of a spine at the posterior end of the dorso-median plate, and in many details of proportion of all the bones. It is certainly specifically new and may have to be referred to a new genus.

'The Natural History Museum contains a single specimen of the same form, which came from Dr. R. H. Traquair's collection and bears the name "Newark" scratched on the back. I have reasons for believing that this is the specimen determined by Traquair as *C. decipiens*, which is said by Flett [1] to have been found by Mr. M. Spence in the Eday sandstones of Newark Bay, Deerness. It is an interesting fact that this form, although now known from two localities, has not yet been found in association with *Tristichopterus*: it is possible that it is restricted to a definite horizon. In any case, it is very desirable that further collecting should be carried out at the localities at which it has been found.

'The collections from S. Ronaldshay are interesting. From the Rousay flags of a quarry near Helliar there is a badly preserved bone which is apparently a posterior ventro-lateral of an Antiarchan, differing from any which I know; but perhaps the *Asterolepis* found immediately below the Eday sandstones in several localities, including N. of Sandside, Deerness.

'The Rousay flags of Bloie Geo, Hoxa Head, have yielded a fragment apparently of *Osteolepis microlepidota*, not previously recognised from Orkney.

'A flagstone band in the yellow sandstones (Lower Eday Beds) of the Steis, Harrabrough Head, has yielded a number of good specimens of *Tristichopterus alatus* Eg. and *Pentlandia* (*Dipterus*) *macropterus* (Traq.), but no remains of *Microbrachius*. These are typical of the John o' Groats Beds, the equivalent of the Eday Beds, as pointed out by Flett.[2]

'*Tristichopterus alatus* Eg. is again represented by a fish from a loose block on the beach north of Strang Quay, Sanday.

'From 150 yards west of Dogs Geo, Muckle Skerry, Pentland Skerries, there are three specimens of *Coccosteus decipiens*, showing that the horizon is below the Eday Beds.'

F. L. KITCHIN.

[1] Flett, Sir J. S., 'The Old Red Sandstone of the Orkneys,' *Trans. Roy. Soc. Edinb.*, vol. xxxix, part ii, 1898, pp. 386, 387.
[2] *Op.cit.*, p. 420.

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2.—PALAEOBOTANICAL WORK

With the assistance of Mr. S. W. Morgan of the Palaeontological Department, work has been continued on the catalogue of specimens in the Kidston Collection of fossil plants, and this is now complete and ready for the press. Specimens which have been figured, described, or specially mentioned have been indicated in the catalogue in the form of footnotes. The collection comprises over 7,000 specimens, of which 840 have been figured, and these include 167 type specimens. All available information with regard to the fossils has been given. The collection has already been made considerable use of by palaeobotanists.

My services have been required in the field on several occasions this year. Mr. J. Pringle and I have visited two coalfields and our joint work on the Coalbrookdale area is embodied in the Wolverhampton Memoir now in the press. In South Wales we visited the Merthyr district, at present undergoing revision, and collected a large and representative suite of fossil plants and animals from the Coal Measures and Millstone Grit. The results of this work will duly appear in the second edition of the Merthyr Memoir. During the course of the work in South Wales a number of fragments of fossil wood were obtained from the Ganister Quarry, half a mile W.S.W. of Pant Station, near Dowlais. These are of special interest in view of the specimen of petrified wood previously collected by Mr. Pringle from the ' Penlan Quartzite ' and identified by Mr. J. Walton as *Dadoxylon* cf. *materiarum* Dawson.[1] This was a fairly large block in an exceptionally good state of preservation, but the pieces now found are small and badly preserved. It was not possible to obtain more than one section from each specimen. The fossils can be identified, however, as *Dadoxylon sp.*, and this constitutes the second record of the genus from the basal quartzite of the Millstone Grit.

I have collected a number of fossil plants from the exceedingly barren horizon of the Pennant Rock (Staffordian Series) of the Somerset and Bristol Coalfield, and these will be described at a later date.

Amongst the specimens examined during the year was a piece of gymnospermous wood collected by Mr. J. W. Tutcher, M.Sc., from the upper part of the Bucklandi Zone of the Lias at Rockhill, near Radstock. The wood was badly preserved, but the pitting on the radial walls appears to be multiseriate, and some of the tracheids are resiniferous. The xylem-rays are comparatively few and range from 2 to 5 cells in height. No pits are observable on their radial walls, and resin canals and xylem-parenchyma are absent. The specimen is referred to *Dadoxylon sp.* Other pieces of fossil wood from the Lias at Keynsham, near Bristol, were sent in by Mr. A. W. Coysh. They had the appearance of jet, but, on being sectioned, showed no structure. R. CROOKALL.

[1] ' Summary of Progress ' for 1926, Appendix V, p. 126, pl. 1.

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3.—PETROGRAPHICAL WORK

The work of the Petrographical Department has been connected mainly with the areas recently surveyed or in progress of surveying.

The re-survey of the Cheviot region by Messrs. Anderson and Burnett has largely substantiated the work of Kynaston and other observers who had paid special attention to the rocks of this district.

The great mass of lavas of Old Red Sandstone age are remarkable for their consistency. They are mainly augite and pyroxene andesites occasionally showing a distinct leaning towards an albitic or dacitic facies.

The granite has been found to be somewhat variable both in texture and composition, but generally rich in albitic and perthitic felspars. Recent work has demonstrated that it becomes at its margin a fine textured granophyre that has tongued and veined the rocks into which it has been intruded. This marginal portion shows local contamination by the partial or complete absorption of xenolithic material derived mainly from the andesitic lavas. Further, it has produced an intense metamorphism of the older rocks with which it comes in contact. The lavas for some hundred yards from the main contact show more or less complete recrystallization, especially in the ground-mass, into fine textured pyroxene-granulites. The extreme metamorphic effects of the granite are very well displayed in the highly-veined cappings of lava which rest upon the granite, well within its peripheral limits. These cappings are of particular interest for they aid considerably any deliberations as to the mode and form of the main intrusion, as well as furnish us with the best examples of contact-phenomena.

The re-survey has shown that the dykes which include porphyrites, quartz-porphyries and felsites cannot be separated as regards age from each other, and in no case has the granite margin been observed to truncate any of them. All types alike appear to cut the granite and to be a later phase of intrusion. The radial distribution of the dykes with regard to the granite has been endorsed, but their number has been found to be much greater than was previously supposed.

The granite itself, as is well known, differs from most other British granites in containing both augite and rhombic pyroxene. The occurrence of these ferromagnesian minerals, which are absent from the marginal portion of the mass except where provedly xenolithic, appears to be sporadic, and their existence as normal constituents of the granite is open to question.

The variability of the granite and the presence of unusual ferromagnesian constituents are features that will be made a matter of special concern, and on which a considered opinion as to their significance will be given at a later date.

Tourmaline has been described as a local constituent of the

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granite, but until the re-survey it was not realized that this mineral had a wide distribution. On the north side of the granite-mass the granophyric marginal variety has been subjected to more or less intense pneumatolytic action with the destruction of felspar, the development of pneumatolytic micas, and the widespread crystallization of tourmaline. In some cases the resulting rocks compare quite closely with the luxullianite and other tourmaline-bearing rocks of Cornwall and Devon.

The pneumatolytic effects are not confined to the granite alone, but have occasionally spread well into the metamorphic zone of the granite, where the Lower Palaeozoic sediments have been highly tourmalinized.

That this pneumatolytic phase represents a late stage in the intrusive history of the Cheviot rocks is clearly demonstrated by the fact that tourmalinization has in certain cases spread to the porphyritic dykes that cut the granite and which are the latest expression of the intrusion of the granite magma. Further, there has been mineralization with attendant tourmalinization of certain north-and-south crush-lines that traverse the granite and which must have been formed well after its consolidation.

H. H. THOMAS.

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4.—CHEMICAL WORK

The quantitative determinations completed in 1927 were mainly for the Scottish Memoirs, though some interesting specimens from Cornwall have also been analysed.

841. *Albite-diabase.* Intrusion. South side of Newlyn Pier, Land's End. 6-in. map, Cornwall, 74. S.W. Slice No. E13479.

842. *Diabase-hornfels.* Carn Kenidjack, N.W. of St. Just. 6-in. map, Cornwall, 67 S.W. Slice No. E13481.

862. Mineral, probably *Cummingtonite.* Contact-altered Greenstone. Kenidjack, near St. Just. 6-in. map, Cornwall, 67 S.W.

849. *Granite.* At edge of Bodmin Moor Mass. De Lank Quarry. St. Breward, near St. Tudy. 6-in. map, Cornwall, 20 S.E. Slice No. E13907.

843. *Porphyry.* Inclusion in granite. From new shaft of Botallack Mine, W.N.W. of St Just 6-in. map, Cornwall, 67 S.W. Slice No. E13480.

Lab. Nos.	841	842	862	849	843
SiO_2	61.59	47.07	53.12	71.86	68.89
Al_2O_3	17.85	20.20	2.78	14.63	15.11
Fe_2O_3	2.19	0.00	0.25	0.15	0.37
FeO	4.30	12.73	22.46	1.26	3.14
MgO	1.02	10.09	15.46	0.66	0.70
CaO	0.53	2.14	2.26	0.87	1.21
Na_2O	7.36	1.48	—	2.92	2.35
K_2O	1.95	1.97	—	5.32	5.66
$H_2O \geq 105°C$ ...	1.71	1.50	3.33	0.84	1.05
$H_2O < 105°C$ ...	0.55	0.16	—	0.15	0.25
TiO_2	0.71	2.12	0.21	0.50	0.74
P_2O_5	0.12	0.12	—	0.42	0.38
MnO	0.11	0.11	0.27	0.06	0.02
ZrO_2	—	—	—	0.02	0.01
F	0.00?	—	—	0.03	0.04
FeS_2	0.11	0.47	—	0.31	0.12
Cr_2O_3	—	0.02	—	—	—
BaO	—	—	—	0.03	0.03
Li_2O	—	0.03	—	0.00	0.02
Less O for F ...	—	—	—	0.01	0.02
Totals ...	100.10	100.21	100.14	100.02	100.07
Analysed by ...	B. E. Dixon.		R. Sutcliffe.		B. E. Dixon.

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837. *Nepheline-basalt*, with nepheline partly fresh and olivine decomposed. Lava of New Red Sandstone (? Permian) age. Quarry, 450 yds. E. 5° N. of Grassmilees, ¾ m. S.E. of Mauchline. 6-in. map, Ayrshire, 29 S.W. Slice No. S25241.

838. *Olivine-basalt*, with olivine fresh and doubtful pseudomorphs after Nepheline. Lava of New Red Sandstone (? Permian) age. E. end of railway cutting, Tarbolton Station. 6-in. map, Ayrshire, 28 S.W. Slice No. S25246.

839. *Alkaline Olivine-dolerite* or *Olivine-basalt*, of Kylite suite, with fresh porphyritic olivine and augite, and with nepheline mostly decomposed. Sill of New Red Sandstone (? Permian) age, intruded into Millstone Grit. Quarry, Craigs of Kyle, 1¼ m. W.N.W. of Rankinston Station. 6-in. map, Ayrshire, 40 N.W. Slice No. S25252.

840. *Hypersthene-andesite*, with fresh felspars, including small labradorite phenocrysts, and also partially fresh hypersthene. Lava of Lower Old Red Sandstone age. Near shore, 540 yds. N.W. by W. of Dunure Station. 6-in. map, Ayrshire, 38 N.E. Slice No. S25255.

864. *Hornblende-trachyandesite*. Lava flow. Right bank of Cleuchearn Burn, 250 yds. 10° E. of S. of E. corner of Cleuchearn Lodge, East Kilbride. 6-in. map, Lanarkshire, 22 N.E. Slice No. S25755.

865. *Pyroxene-trachyte* or *Trachyandesite*. Lava flow. 115 yds. N.N.W. of summit of Drumreevough, Avondale. 6-in. map, Lanarkshire, 22 S.E. Slice No. S25756.

Lab. Nos.	837	838	839	840	864	865
SiO_2	39.35	45.62	45.70	58.88	54.66	59.57
Al_2O_3	11.60	14.18	12.32	15.86	15.90	16.12
Fe_2O_3	9.31	2.95	0.99	2.40	3.06	3.44
FeO	4.76	8.40	9.64	3.46	4.11	3.11
MgO	10.58	9.69	12.45	4.40	2.91	1.46
CaO	10.55	9.25	10.12	5.75	3.91	2.65
Na_2O	3.06	3.61	2.74	2.70	4.66	6.03
K_2O	0.86	1.48	1.04	2.02	3.81	4.34
$H_2O >$ 105°C ...	3.76	2.29	2.12	0.65	2.13	1.08
$H_2O <$ 105°C ...	1.44	0.27	0.16	1.74	1.83	0.63
TiO_2	3.38	1.61	1.50	1.17	1.48	0.77
P_2O_5	0.82	0.47	0.33	0.22	0.43	0.21
MnO	0.79	0.32	0.29	0.52	1.14	0.78
CO_2	0.19	0.05	0.07	0.09	0.24	0.12
Cl	0.05	0.03	0.01	0.00?	—	—
FeS_2	0.03	0.00	0.00	0.00	—	—
NiO, CoO	0.03	0.03	0.02	0.03	0.00	0.00
BaO	0.01	0.02	0.03	0.04	0.12	0.13
Li_2O	0.00?	0.00	0.00?	0.00?	0.00?	0.00?
Less O for Cl ...	0.01	0.01	—	—	—	—
Totals ...	100.56	100.26	100.13	100.02	100.39	100.44
Analysed by ...	E. G. Radley.					

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854. *Staurolite-garnet-mica-schist.* Belt in Moine Series. ⅛ m. S.E. of Cairn on Cnoc an Daimh Beag, 1⅛ m. E. of Loch Meadie. 6-in. map, Sutherland, 43 S.W. Slice No. S25686.

856. *Modified Pelitic Schist* within Granite Complex (early stage). Part of Moine Series and Granite Complex. 2¼ m. S.E. by S. of Klibreck Farm. 6-in. map, Sutherland, 54 S.W. Slice No. S25688.

855. *Modified Pelitic Schist* within Granite Complex (middle stage). Part of Moine Series and Granite Complex. 2⅜ m. S.E. by S. of Klibreck Farm. 6-in. map, Sutherland, 54 S.W. Slice No. S25687.

857. *Modified Pelitic Schist* within Granite Complex (advanced stage). Part of Moine Series and Granite Complex. 2⅛ m. of S.E. of Klibreck Steading. 6-in. map, Sutherland, 54 S.W. Slice No. S25689.

Lab. Nos.	854	856	855	857
SiO_2	63.98	61.11	62.28	59.25
Al_2O_3	17.68	18.33	17.69	18.48
Fe_2O_3	2.23	1.14	1.09	1.24
FeO	4.76	5.47	5.25	6.78
MgO	3.18	1.75	1.67	2.30
CaO	1.05	1.66	2.29	2.51
Na_2O	1.10	2.64	3.25	3.78
K_2O	4.16	4.41	3.60	3.64
$H_2O \geqslant 105°C$ ...	1.18	1.51	1.43	0.72
$H_2O \lessdot 105°C$ ...	0.10	0.13	0.13	0.12
TiO_2	0.85	1.15	1.08	1.18
P_2O_5	0.08	0.08	0.08	0.08
MnO	0.05	0.11	0.07	0.08
CO_2	—	0.00?	—	—
F	—	0.00?	0.00?	—
FeS_2	0.00?	0.22	0.04	0.00?
Fe_7S_8	—	0.12	—	0.00?
Cr_2O_3	0.01	0.02	0.02	0.00?
BaO	0.00?	0.06	0.00	0.05
Li_2O	0.00?	0.00?	0.00?	0.00?
Totals ...	100.41	99.91	99.97	100.21
Analysed by ...	B. E. Dixon.			

850. *Pitchstone* (Corriegills Type). 20 ft. sill in New Red Sandstone. Lower pitchstone scarp above path near South Corriegills, ¼ m. E.S.E. of Dun Dubh (the more northerly of two sills midway between Dun Dubh and Dun Fioun), Arran. 6-in. map, Bute (Arran), 250 N.W. Slice No. S25614.

851. *Olivine-bearing Pitchstone* (Glen Shurig Type). Dyke in Old Red Sandstone. Farm road, 65 yds. from String Road, at B.M. 244.8, Glen Shurig, ½ m. S.W. of Brodick Church, Arran. 6-in. map, Bute (Arran), 244 S.E. Slice No. S25615.

852. *Pitchstone* (Tormore Type). Composite dyke (Judd's No. 2 Dyke —*vide* Q.J.G.S., vol. xlix, 1893, p. 555). Tormore shore, S. of Machrie Bay, Arran. 6-in. map, Bute (Arran), 248 S.E. Slice No. S25621.

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853. *Tholeiite* (cf. Brunton type) associated with pitchstone. Basic member of pitchstone tholeiite composite dyke (Judd's No. 2 Composite Dyke). Tormore Shore, S. of Machrie Bay, Arran. 6-in. map, Bute (Arran), 248 S.E. Slice No. S25622.

Lab. Nos.	850	851	852	853
SiO_2	73.20	72.33	71.51	54.52
Al_2O_3	10.75	10.45	10.55	14.53
Fe_2O_3	0.95	1.00	0.79	2.21
FeO	1.02	2.14	2.22	6.06
MgO	0.15	0.11	0.52	5.61
CaO	0.76	1.44	1.52	8.08
Na_2O	3.78	4.09	4.12	3.66
K_2O	4.20	3.49	3.48	1.14
$H_2O >$ 105°C ...	4.52	4.02	4.07	0.93
$H_2O <$ 105°C ...	0.18	0.16	0.19	1.95
TiO_2	0.16	0.30	0.33	0.87
P_2O_5	0.19	0.16	0.24	0.21
MnO	0.37	0.50	0.42	0.24
NiO, CoO	0.00	0.00	0.00	0.00
BaO	0.05	0.08	0.08	0.03
Li_2O	0.00	0.00?	0.00	0.00
Totals ...	100.28	100.27	100.04	100.04
Analysed by ...	E. G. Radley.			

R. Sutcliffe.

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I.—A Gravitational Survey over the Swynnerton Dyke, Yarnfield, Staffordshire

By W. F. P. McLintock, D.Sc., and J. Phemister, M.A., B.Sc.

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In the *Summary of Progress* for 1926 an account was given of the use of the Eötvös Torsion Balance in the investigation of geological structure in south-west Persia and the results there described seemed sufficiently promising to warrant the Survey in employing the method in this country. Accordingly in the spring of this year an instrument was acquired from Messrs. L. Oertling, Ltd., of type similar to that described in their handbook[1] and fully discussed by Captain Shaw and Mr. Lancaster-Jones in a recent series of articles in the Mining Magazine[2]. A preliminary note on the first field test with this balance has already appeared[3], but in view of the increased interest now being taken in geophysical methods of investigation and the lack of published details of actual field work, the fuller account that follows may, it is hoped, be of service to those interested in gravitational surveys.

THE INSTRUMENT

The large-size Eötvös Torsion Balance as made by Messrs. Oertling is so constructed that it may be used both for photographic and visual observation. Prior to work in the field, a series of tests was carried out in the laboratory and it was found possible by both methods of observation to measure gradients accurately to 1E (= 1×10^{-9} c.g.s. units). Slabs and cylindrical cores of rock of definite dimensions and weights were placed at known distances from the balance and their gravitational effects measured. These when compared with the values obtained by calculation gave satisfactory agreement.

In the field, however, several disturbing factors prevent the balance from working so smoothly and accurately. These have been noted by previous workers and in the most modern type of instrument and protecting tent attempts have been made to eliminate the disturbances with, as far as our experience goes, only partial success.

Thus we found it impossible to get reliable readings during the day. Visual observation on several days showed that the beams were never actually at rest even when left for several hours in one azimuth, the progressive change over a period of four or five hours amounting in some cases to as much as 40 scale divisions. Shortly after sunset the balance settled down and gave good repeats in the various azimuths till sunrise when the disturbance was almost

[1] '*The Eötvös Torsion Balance*,' L. Oertling, Ltd., London.

[2] 'The Theory and Practical Employment of the Eötvös Torsion Balance,' *Mining Magazine*, vol. xxxvi, 1927, pp. 201-212, 274-282, 339-347 ; vol. xxxvii, pp. 14-22.

[3] 'A Gravitational Survey over the Swynnerton Dyke, Yarnfield, Staffordshire,' *Mining Magazine*, vol. xxxvii, 1927, pp. 362-365.

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immediately manifested and readings ceased to be satisfactory.

Photographic recording was also found to be uncertain. By this method the readings are taken automatically each hour successively in the various azimuths on a photographic plate, the process being controlled by clockwork attached to the balance and its protecting tent. In the laboratory this method works satisfactorily but in the field fluctuations of temperature, deposition of moisture on the balance parts with consequent liability to sticking of the suspended systems, vibration of the beams due to wind and other causes, all render photographic recording with this type of balance and protecting tent rather uncertain and after a continued trial we discarded it in favour of visual observation at night.

The protecting tent or hut provided with the balance is circular in section and is made in two parts readily clamped together. It is provided with three windows situated at the N., 120° and 240° positions respectively and as the tent is only three feet in diameter it is possible to read the balance scales visually without opening the tent. The advantage of this is apparent as the balance is completely enclosed and protected from external influences during a series of readings but there are certain drawbacks inherent to the arrangement in the field :

(*a*) Frequently during the night the interior surface of the observation windows becomes so obscured by moisture that it is impossible to read the scales.

(*b*) The small diameter of the tent brings the shielding surface very near the balance and so renders protection from temperature changes, solar radiation, etc., possibly less than it ought to be. This may partly explain the difficulty of getting reliable results during the day.

(*c*) From the same cause the foot of the tent lies very near the levelling base screws of the balance and any vibration of the tent due to wind is thus readily communicated to the base of the balance and so to the suspended systems. As a result, during high wind, visual reading of the scales is made difficult and photographic recording uncertain.

These disadvantages would probably be largely overcome by enclosing the hut and balance in an outer tent, which would have to be of considerable size, but owing to the advisability of limiting the amount of material to be transported this plan was not adopted.

The great advantage of the circular type of tent lies in the ease with which it permits of the balance being transported from station to station without dismantling either the tent or the instrument. This is done by attaching the balance, the suspended systems and moving parts having been clamped, by means of two sets of hooks and rigging-screws to the interior of the tent and transporting the whole bodily on a specially constructed trolley to the next station where balance and tent are immediately set up. The saving in time and labour over the other method whereby the tent and balance are dismantled, transported in parts to the next station and reassembled, is

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considerable and we have found the arrangement work well in varied conditions of terrain and weather.

THE CALCULATION OF TERRAIN EFFECTS

As pointed out in a previous paper[1] the quantities obtained from the balance readings are the resultant values arising from (1) the departure of the earth from a truly spherical form—the so-called normal effect—easily calculated from Helmert's formula, (2) the variable manner of distribution of rocks of different specific gravity in the earth's crust, and (3) variations in level and superficial distribution of mass in the neighbourhood of the balance, more particularly the *terrain effect* caused by changes in level of the surface of the ground within a radius of 100 ft. from the balance. The method of evaluating the terrain effect has been frequently described. A good level, an accurately divided levelling staff and a tape graduated in feet and 200 ft. long are necessary. Depending on the nature of the terrain it is necessary to take levels in 8, 16, or 32 azimuths around circles with radii of 5 ft., 10 t., 15 ft., 20 ft., 30 ft., 50 ft., 100 ft., from the balance station. If the ground in the immediate vicinity of the station point is irregular it may be advisable to take levels around a circle of 2½ ft. radius. The levelling must be done accurately to $\frac{1}{100}$ ft., particularly for the circles of smaller radius, and from the levelling data so obtained the terrain effect is evaluated by the method of Schweydar[2], who gives coefficients calculated for measurements made in the metric system. The following coefficients, which have been carefully checked, were calculated for measurements made in feet from Schweydar's general formulae. They differ materially from the coefficients published in " The Eötvös Torsion Balance ", L. Oertling, Ltd., London, and by Fordham[3], and to a lesser extent from those given by Shaw and Jones[4].

	I	II	III	IV	V	VI	VII	VIII	IX	X
	2½ ft.	5 ft.	5 ft.	10 ft.	15 ft.	20 ft.	30 ft.	50 ft.	100 ft.	200 ft.
U_{xz}	26.62	22.31	35.6	9.14	2.79	1.48	.916	.435	.142	.0315
U_{yz}	26.62	22.31	35.6	9.14	2.79	1.48	.916	.435	.142	.0315
U_{Δ}	23.2	38.2	49.8	27.1	13.24	10.11	9.19	7.27	4.34	1.81
U_{xy}	23.2	38.2	49.8	27.1	13.24	10.11	9.19	7.27	4.34	1.81

If levelling is begun on the 5-foot circle the coefficients to be used are those in columns III to X; if levels are taken on the 2½-foot, 5-foot, &c. circles the coefficients to be used are those in columns I, II, IV to X.

[1] 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, p. 170.
[2] Schweydar, W., *Zeitschrift für Geophysik*, I Jahrgang 1924/25, Heft 3, pp. 81-89.
[3] 'Oil Finding by Geophysical Methods,' *Journ. Inst. Petrol. Tech.*, vol. xi, 1925, p. 456.
[4] *Loc. cit.*, pp. 281-282.

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In Schweydar's analysis of the terrain effect it is assumed that radial lines on the surface of the ground between two points on adjacent circles are straight. The terrain over which the survey was made is pasture with pronounced ridges and furrows of former cultivation. The furrows are in places about six inches deep and the horizontal distance from trough to crest is only about five feet. In many cases the assumption referred to above was not valid within the 5-foot circle. It was therefore considered advisable to compare the values for the terrain effect calculated from levellings in eight and in sixteen azimuths with and without the inclusion of levellings on the 2½-foot circle. The terrain effects so calculated at four stations are shown in the following table.

Station.	Gradient component.	First circle at 5 ft.		First circle at 2½ ft.	
		8 azimuths.	16 azimuths.	8 azimuths.	16 azimuths.
4	U_{xz}	+ 0.71	+ 0.53	+ 2.55	+ 2.57
	U_{yz}	+ 11.3	+10.9	+ 9.84	+ 9.47
6	U_{xz}	+ 2.49	+ 3.52	+ 2.56	+ 3.55
	U_{yz}	+15.04	+15.5	+13.81	+13.7
8	U_{xz}	+ 7.01	+ 6.72	+ 7.03	+ 6.46
	U_{yz}	−11.27	−10.05	−11.25	−10.40
5	U_{xz}	+ 3.81	+ 5.44	+ 3.83	+ 5.80
	U_{yz}	+ 5.16	+ 5.81	+ 6.50	+ 6.45

Bearing in mind that the furrows run almost due magnetic east and west we should expect the U_{xz} component to be more affected by levelling the 2½-foot circle than the U_{yz} component. This is illustrated by Station 4. At Station 6 it may be noted that the U_{yz} component is the more affected. In this case a drain channel about nine inches deep lay five feet west of the station point. The advisability of levelling stations 5 and 8 in sixteen azimuths is clearly shown by the figures in the table, but for these stations it was sufficient to commence levelling on the 5-foot circle. A further point may be noted with regard to the terrain. The material constituting the terrain is a marly, somewhat gravelly, drift which has a specific gravity of 1.66 when dry. When saturated with water after heavy rain it was found to have a specific gravity of 1.79.

The importance of accurate terrain corrections is strikingly illustrated by Figs. 2 and 3 (pp. 6, 7), which show respectively in graphical form the results before and after correction for terrain and normal effects.

NATURE AND RESULTS OF THE TEST

The nature of the test is indicated in Fig. 1. The Swynnerton

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(A). *Swynnerton Dyke. Line of traverse, looking east. The white tabs indicate stations.*

(B). *Swynnerton Dyke. Line of traverse, looking west. The white tabs indicate stations.*

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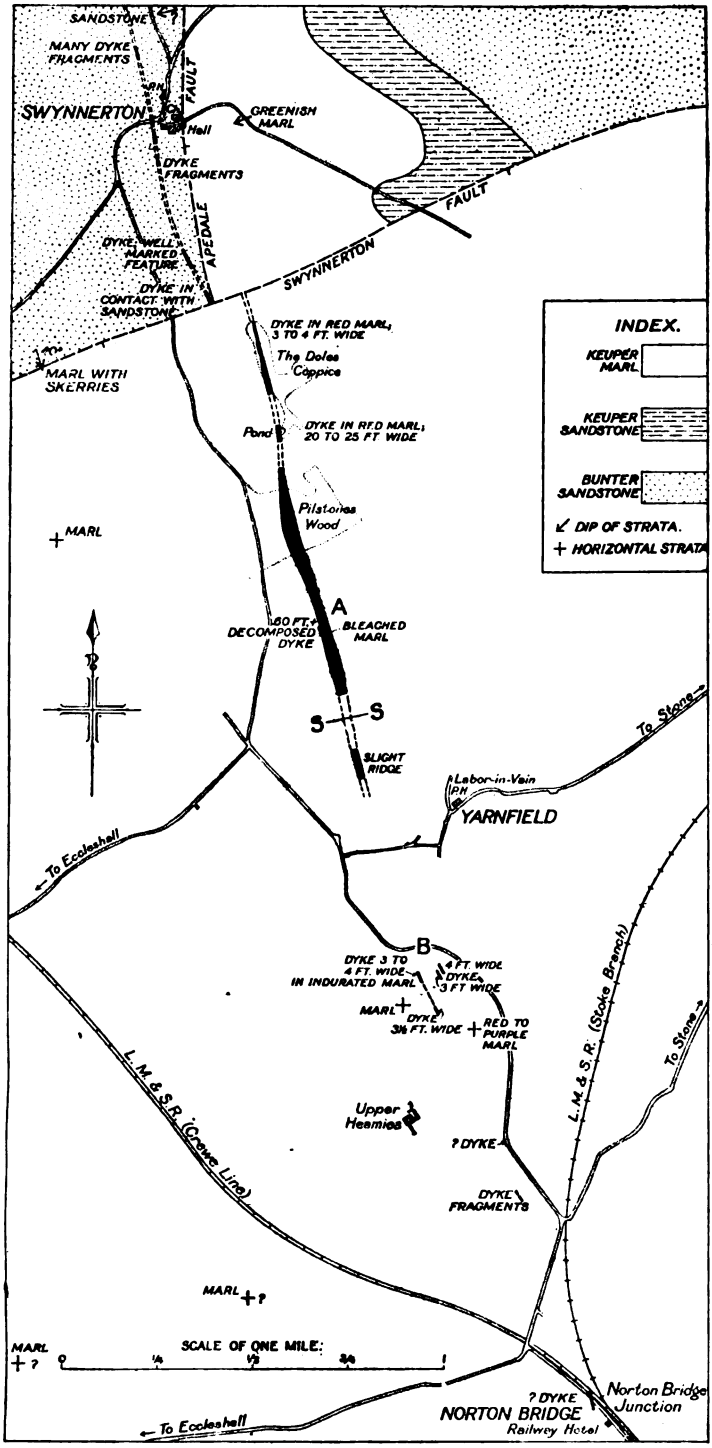

FIG. 1.—*Sketch-map showing the outcrop of the Swynnerton Dyke.*

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dyke[1] is a nepheline-basalt of post-Triassic age. Southwards from Swynnerton it has been traced practically continuously for a distance of one and a half miles. Thereafter its course lies through a flat drift-covered country for one mile, when it is again exposed in the hillslope half a mile south by west of Yarnfield. The traverse by torsion balance was made at right angles to the presumed course of the dyke through this drift-covered area at a position 2,000 ft. 35° to 40° north of west of the inn at Yarnfield. The line SS in Fig. 1 indicates the exact site in relation to the various exposures. The results plotted in Fig. 2 show the gradient components parallel to the line of traverse as calculated directly from the balance observations.

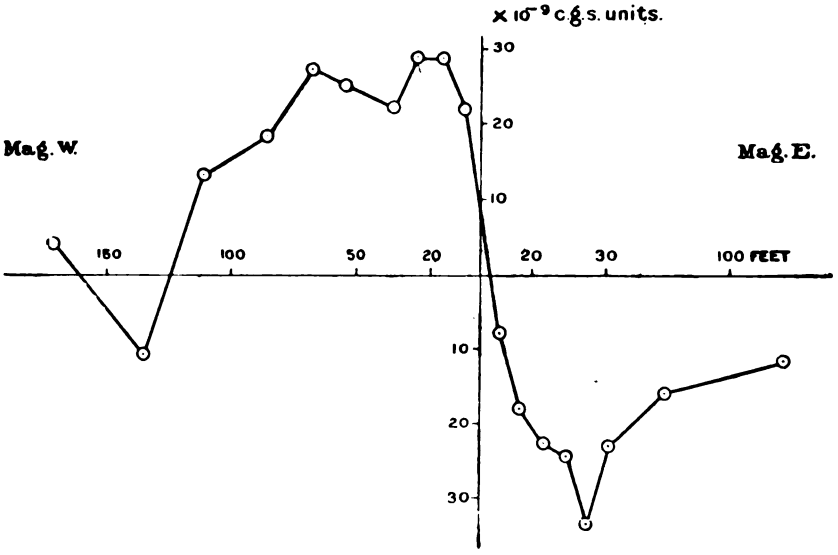

FIG. 2.—*Components of total gradients parallel to the line of traverse.*

After application of the normal and terrain corrections the residual components parallel to the line of traverse, which are due only to subterranean structure, fall on an almost smooth curve as shown in Fig. 3. The resultant residual gradients are represented in magnitude and direction by arrows in the plan, Fig. 4, from which we note that the average direction of the gradients is parallel to the line of traverse and therefore at right angles to the presumed course of the dyke. But the variation of the gradients is more clearly shown by the continuous curve of Fig. 3. The ordinates of this curve represent the values of the components of the gradient parallel to the line of traverse and the abscissae the distances between the stations. Positive ordinates indicate that the gradient-components[2] parallel

[1] Robertson, T., 'The Country between Stafford and Market Drayton' (*Mem. Geol. Surv.*), 1927, pp. 65-69.

[2] The gradient components perpendicular to the line of traverse are relatively very small and have not been considered. Significant results could have been obtained from them only if two or three short parallel traverses had been made.

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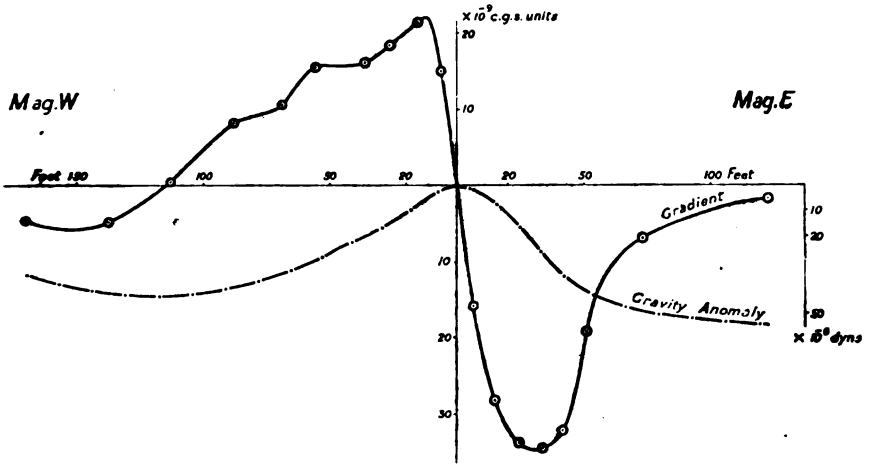

FIG. 3.—*Components of corrected gradients parallel to the line of traverse.*

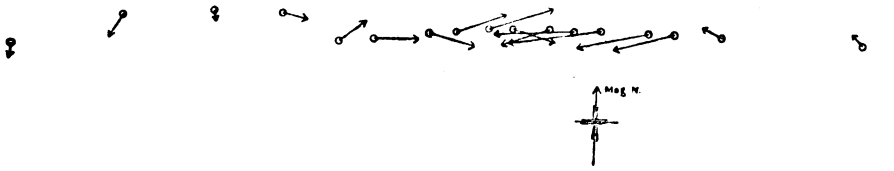

FIG. 4.—*Plan of gradients obtained in survey across the Swynnerton Dyke.* (*Scales:* (1) *Horizontal plane* 1 *cm.* = 26 *ft.*; (2) *of arrows* 1 *mm.* = 2.6 *E.*)

to the line of traverse are directed to the right, negative ordinates indicate that they are directed to the left. It will be observed that there is a point on the line of traverse towards which the gradients are directed, and that to the east and west of this point the magnitude of the gradients increases and decreases very rapidly. This indicates that a heavy mass of rock with abrupt east and west terminations exists approximately under the position of zero gradient. The actual increase in the force of gravity due to this heavy mass can be obtained by integration of the gradient curve, and is shown in Fig. 3 by the interrupted curve, the so-called gravity anomaly curve, from which it is apparent that the increase is approximately 50×10^{-6} dyne, that is, 1/20,000 dyne.

In addition to the gradients of gravity the balance observations also allow us to calculate the horizontal directing tendency (briefly H.D.T.) or curvature vector, and this quantity is usually plotted in plan along with the gradients. In the present case, however, in order to avoid a complicated diagram it is best to keep the plans separate. In Fig. 5 the small circles indicate station points and the lines through them represent the magnitude and direction of the H.D.T. at these points corrected for normal and terrain effects. The direction shows the direction of least curvature of the level surface at

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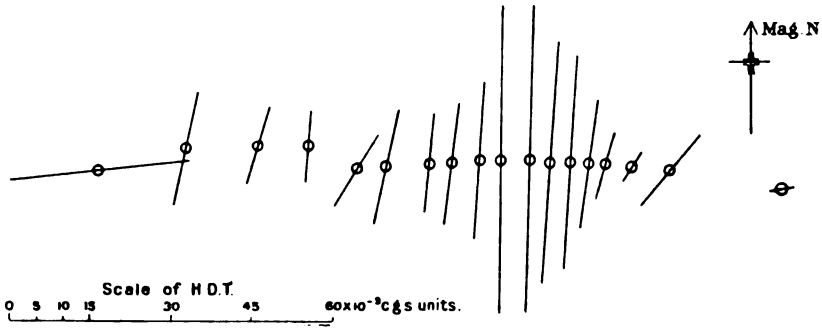

FIG. 5.—*Plan of residual H.D.T. obtained in the survey over the Swynnerton Dyke. For distances between stations see Figs.* 3 *and* 4.

the station and, from theory, this direction at points close to and over a dyke is parallel to the strike. The length of the line is proportional to the greatest difference in curvature of the level surface at each station. This maximum difference of curvature varies from station to station and is greatest at or nearly above the centre of the dyke. At or very near this point the gradient is zero.

The results plotted in Fig. 5 and in the gradient plan Fig. 4, when compared with the geological map, Fig. 1, show a series of curvature vectors (= H.D.T.) parallel to the known strike of the dyke and a

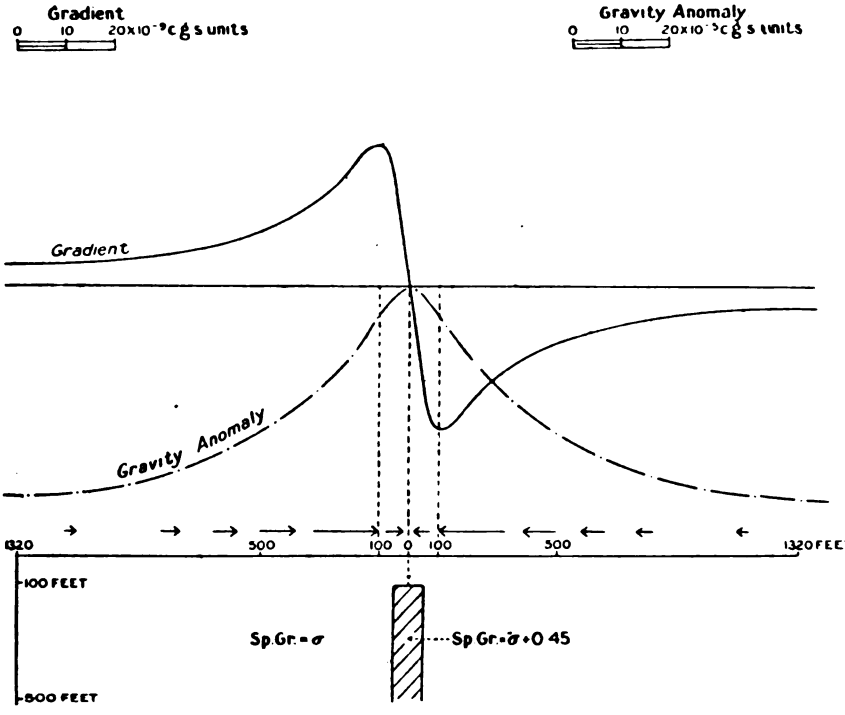

FIG. 6.—*Theoretical gradients for a vertical dyke.*

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series of gradients whose average direction is perpendicular to the curvature vectors and to the strike. Further, the striking increase in H.D.T. just at the position of reversal of rapidly varying gradients is additional verification of the existence beneath the surface of a heavy rock-mass with steep east and west terminations such as has already been indicated by the gradients.

INTERPRETATION OF THE RESULTS

In Fig. 6 is shown the curve of gradients calculated for a vertical dyke of width 100 ft. with its top 100 ft. below the centre of gravity of the balance. There is sufficient resemblance in general shape between this theoretical curve and the experimental gradient curve of Fig. 3 to indicate that the torsion balance has detected a dyke-like structure. The differences, however, are considerable and the main points of difference to be noted are (i) the greatest positive

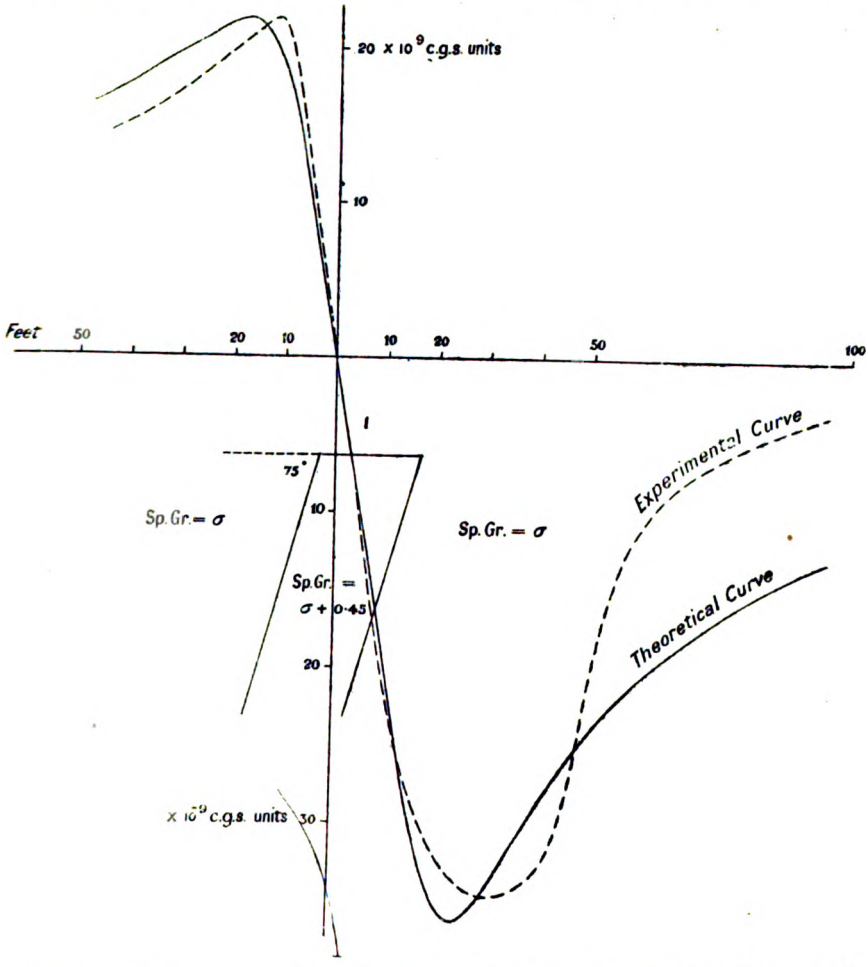

FIG. 7.—*Theoretical gradients for an inclined dyke and experimental results of actual survey.*

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gradient is much less numerically than the greatest negative one, and (ii) the gradients left of the maximum decrease more slowly than do the gradients right of the minimum. If the gradient curve for a dyke dipping at a high angle to the west be constructed (using the formula given below), a much closer correspondence to the experimental curve is obtained. The fact that the ratio of the maximum and minimum gradients is considerably different from unity means that the dyke deviates considerably from the vertical. In Fig. 7 the continuous line is the curve of gradients calculated for a dyke 20 ft. wide, depth of top 19 ft. beneath the centre of gravity of the balance, dip 75° W., and with a specific gravity 0.45 greater than the country rock ; the interrupted line is the experimental curve of Fig. 3. Correspondence is now so marked that it may be accepted that the survey has detected the existence beneath the covering of drift of a dyke whose width, depth, and dip are of the same order as those of the dyke shown in Fig. 7.

It may be noted from Fig. 5 that the H.D.T. retains a high value on the right of its maximum for a greater distance than on the left. This supplements the evidence of the gradients that the dip of the dyke is towards the west. The maximum H.D.T. for a dyke with the dimensions mentioned above is 56E, which is in good agreement with the highest value, 58.5E, found during the survey[1].

Determination of the specific gravity of the Swynnerton dyke from specimens gave values varying from 2.85 to 3.0. The country rock at the site of the survey is Keuper Marl, the specific gravity of which is not easily determined but is approximately 2.4 for wet marl. These figures give an average specific gravity difference of 0.52 between dyke and marl and if this be correct the depth given for the dyke is the least depth, that is the top is at least 16 ft. beneath the surface.

The differences between the two curves of Fig. 7 can be explained as the result of irregularities of the surface of the dyke and marl beneath the drift.

The geological evidence and the results obtained with the torsion balance are summarised in the table below. The localities refer to Fig. 1. The position at which the gradient is zero and the H.D.T. maximum lies within the dotted boundaries shown in Fig. 1. The deduced centre of the dyke also lies within the same boundaries.

Swynnerton Dyke

At Pilstones Wood.	At locality A.	At SS.	At locality B.
Width = 200 ft.	Width = 60 ft.	Width = approx. 20 ft. Depth beneath surface = approx. 16 ft. Dip = approx. 75° W.	Three branches whose aggregate width is 11 ft. Dip about 70° W.

[1] The highest value would probably be 60 to 62E.

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METHOD OF CALCULATING DEPTH, ETC., FOR A DYKE OR LODE.

In Fig. 8 let AB be the flat top of a parallel-sided dyke which stretches to a great distance in the horizontal direction perpendicular to AB and which also extends to a great depth.

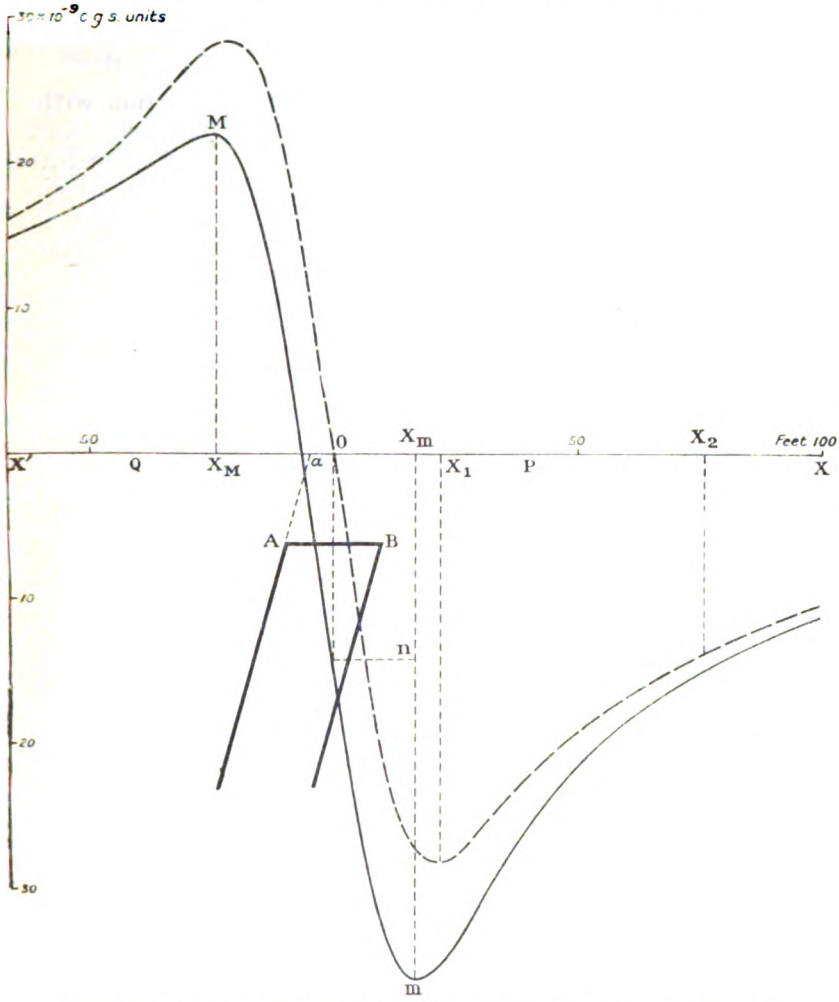

FIG. 8.—*Diagram to illustrate method of calculating depth, etc., of an inclined dyke or lode.*

Let α = angle made by the sides of the dyke with the positive direction X'X

$2l$ = width of top

d = depth of top

σ = difference of specific gravity between dyke and country rock

G = constant of gravitation = 66.6×10^{-9} c.g.s. units

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Then the gradient at any point P on X′X is given by

$$U_{xz}=G\sigma\left\{2\sin^2\alpha\log_e\frac{PB}{PA}-\sin 2\alpha\ (XPB-XPA)\right\}\ldots I$$

or, if the origin of co-ordinates is taken at O vertically above the middle line of the top of the dyke, by

$$U_{xz}=G\sigma\left\{\sin^2\alpha\log_e\frac{(x-l)^2+d^2}{(x+l)^2+d^2}+\sin 2\alpha\ \tan^{-1}\frac{2dl}{x^2+d^2-l^2}\right\}\ldots II$$

The expression I for the gradient is used in conjunction with a scale diagram of the dyke, the lengths PB, PA and the angles XPB, XPA being measured from the diagram and the values substituted in I. In working out the value of the gradient it is to be remembered that the logarithm term is a Naperian logarithm and that the values of the angles must be converted from degrees into radians. The formula for the gradient when logarithms to base 10 are used and when angles are measured in degrees is

$$U_{xz}=G\sigma\left\{4.605\sin^2\alpha\log_{10}\frac{PB}{PA}-\frac{\sin 2\alpha}{57.296}(XPB-XPA)\right\}\ldots III$$

The expression II is used to determine general relations between the depth, width, and dip of any dyke. By equating the derivative of this expression to zero we can obtain the positions X_M and X_m at which the gradient is maximum and minimum, and also we find the general result that

$$X_MX_m=2\sqrt{l^2+d^2}\operatorname{cosec}^2\alpha\quad\ldots\quad\ldots\quad\ldots\quad\ldots\quad IV$$

By substituting in II the values of x corresponding to X_M and X_m the maximum and minimum values of the gradient are found, and further, their sum is found to be

$$X_MM+X_mm=G\sigma\sin 2\alpha\tan^{-1}\frac{2dl}{d^2-l^2}\quad\ldots\quad\ldots\quad V$$

The expression on the right-hand side of V is from II easily seen to be the value of the gradient at O and we have therefore the general result that the algebraic sum of the maximum and minimum gradients is equal to the gradient at the point vertically above the middle of the top of the dyke. Therefore, to find the middle point of the dyke from an experimental gradient curve lay off on mX_m mn equal to X_MM. Then the horizontal line through n will cut the gradient curve in the vertical through the middle point of the top of the dyke.

The following method of obtaining a complete solution to the dyke problem is due to Nikiforov[1].

In the expression II for the value of the gradient let

$$f(x)=G\sigma\sin^2\alpha\log\frac{(x-l)^2+d^2}{(x+l)^2+d^2}$$

and

$$F(x)=G\sigma\sin 2\alpha\tan^{-1}\frac{2dl}{x^2+d^2-l^2}$$

[1] 'Physical Principles of the Gravitational Method of Prospecting,' *Bull. Inst. Pract. Geophys., Leningrad*, vol. 1, 1925, pp. 235-239.

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Then

$$\text{Gradient} = U_{xz}\ (x) = f(x) + F(x)$$

But

$$f(x) = -f(-x) \text{ and } F(x) = F(-x)$$

Therefore

$$U_{xz}\ (x) - U_{xz}(-x) = 2f(x) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \text{VI}$$

and

$$U_{xz}(x) + U_{xz}(-x) = 2\,F(x) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \text{VII}$$

Having obtained the middle point of the dyke as shown above we can, by means of equations VI and VII, break down the experimental curve into two parts corresponding to f(x) and F(x). To obtain the logarithmic part f(x) we make use of equation VI. From the algebraic value of the gradient at any point P subtract the algebraic value at the corresponding point Q, which is an equal distance on the other side of O. Divide the result by 2 and plot the value against P and Q. In this way a curve (the broken curve of Fig. 8) representing the expression

$$G\sigma \sin^2\alpha \log \frac{(x-l)^2+d^2}{(x+l)^2+d^2}$$

is obtained. This expression gives the value of the gradient due to a vertical dyke of width 2l and depth d, and is maximum or minimum when

$$x = OX_1 = \sqrt{d^2 + l^2} \quad \ldots \quad \ldots \quad \ldots \quad \text{VIII}$$

The distance OX_1 is determined from the experimental results. Equation VIII and equation IV are now available for determination of l, d, and α. To obtain a third equation Nikiforov determines the distance OX_2 at which f(x) is half its maximum value. Then the following equation holds.

$$\left[\frac{(OX_2 + l)^2 + d^2}{(OX_2 - l)^2 + d^2}\right]^2 = \frac{OX_1 + l}{OX_1 - l}$$

This simplifies to

$$\left.\begin{aligned} l &= \sqrt{A\,(2OX_1 - A)} \\ \text{where} \\ A &= \frac{\overline{OX_1}^2 + \overline{OX_2}^2}{2\,OX_2} \end{aligned}\right\} \quad \ldots \quad \ldots \quad \ldots \quad \text{IX}$$

In equation IX the numerical values of OX_1 and OX_2 are substituted and l is then calculated. The depth is next determined from equation VIII, and finally, the angle from equation IV.

In an ordinary field survey it is unlikely that the point X_2 can be determined accurately since effects due to subterranean topography and general structure will affect its position considerably. The point on the steep part of the curve f(x) between O and X_1 at which the gradient is half the maximum may then be determined and the abscissae of this point used in equation IX in place of OX_2.

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The value of l so determined will serve as a basis for constructing one or two gradient curves by means of formula I, the values of d and α being of course related to any arbitrary value of l by the equations IV and VIII. The values of l, d and α which give the gradient curve most comparable with the experimental one may then be taken as approximations to the real values for the dyke.

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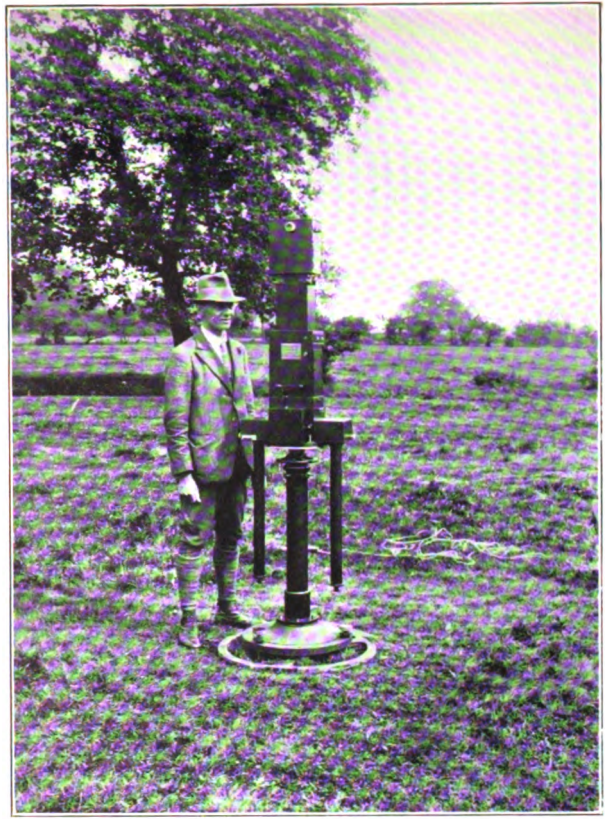
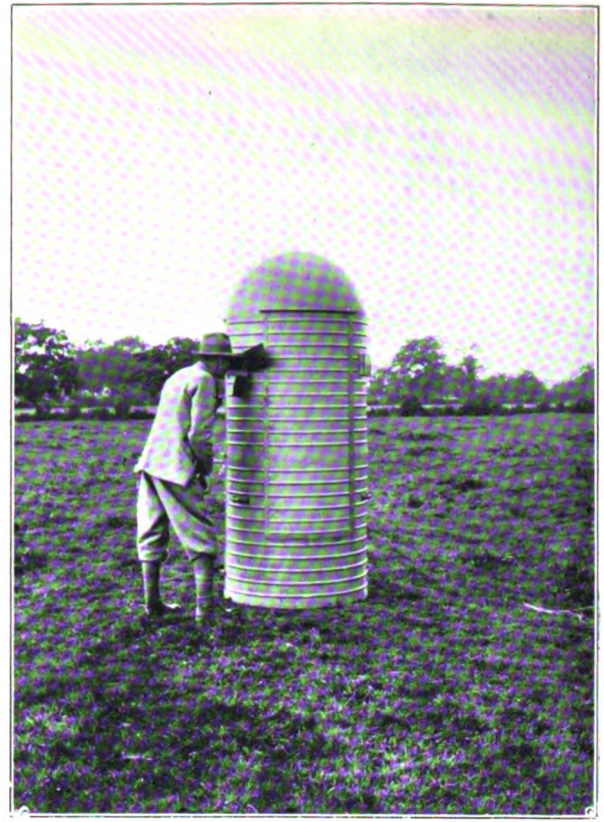


(A). *The Eötvös Torsion Balance.*



(B). *The Eötvös Torsion Balance, showing protecting hut and method of visual reading.*

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II.—THE COCKERMOUTH LAVAS, CUMBERLAND—A CARBONIFEROUS VOLCANIC EPISODE

By T. Eastwood, A.R.C.Sc.

Text-figure 1.

Most geologists are familiar with the maps of the Lake District, which show Skiddaw Slates flanked by igneous rocks referred to the Borrowdale volcanic episode of the Ordovician period. These in turn are ringed about by Carboniferous strata. The Ordovician age of the igneous rocks, with the possible exception of those of Eycott, has been accepted without question.

While surveying the Cockermouth area, however, the writer was struck by the fact that a series of basaltic lavas, previously mapped as Borrowdales, were underlain by a conglomerate unlike anything in the Skiddaw or Borrowdale sequence. Apart from the fact that the lavas were more basic than usual and much less disturbed than is commonly the case in the Lake District, there seemed no reason why, in the absence of normal types of Borrowdale lavas here, they should not belong to that group, especially as the conglomerate does not there appear to contain any of the easily recognised Borrowdale types.

Previous surveyors, Clifton Ward and Goodchild, had noticed the presence of the conglomerate and recorded it as the basal member of the Carboniferous. To account, however, for its position between the Skiddaw Slates and the lavas they either introduced some frankly theoretical faults or ignored it altogether.

Examination in the field, especially between Wood Hall and Redmain to the north of Cockermouth (Fig. 1), makes it perfectly clear that the lavas rest in a normal fashion on the conglomerate. The actual junction is never visible, but in several cases the obscured gap is only about 5 ft. in thickness, and both rocks are seen to make V-shaped outcrops in the ravines of the steep tributaries on the north-west bank of the Derwent. The contact between the conglomerate and the underlying Skiddaw Slate is likewise never actually exposed, but here again the obscured portion is but a few feet in width.

One of the most noteworthy constituents of the conglomerate is Latterbarrow Sandstone—a rock generally acknowledged as being at the summit of the Skiddavian and actually occuring at one place beneath the conglomerate. It follows, therefore, that if the lavas are a rather peculiar type of Borrowdales, then the conglomerate, which obviously precedes them, must be of early Borrowdale age and must mark a period of considerable erosion. This, in fact, was the first assumption pending a petrological examination of the lavas.

On Dr. H. H. Thomas announcing the presence of olivine a

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further and more comprehensive suite was submitted, as the possibility of their not being of Ordovician age was then realised. They were either a new type of Borrowdales, or, by a freak of nature, the Borrowdales were absent and a suite of volcanic rocks of Old Red Sandstone or Carboniferous age occurred here and nowhere else in the Lake District between the Skiddaw Slates and the Carboniferous Limestone.

Since Clifton Ward and Goodchild were familiar with the Borrowdale group and had mapped them, probably from east to west, into the area in question, it was evident that further work was required to extend the knowledge derived from the limited outcrops examined in the south-eastern corner of the One-inch Sheet 22 (Maryport) and the south-western margin of Sheet 23 (Cockermouth) (Old Series Geol. 101 N.W. and 101 N.E.).

Acting upon instructions, the ground to the north-east was examined and the range of the basaltic lavas has been found to extend from the west of Cockermouth, and Redmain north of that town, to the Keswick-Bothel road near Bothelcrags—a total distance of seven miles (Fig. 1)—and their relationship to the overlying limestones has been more clearly established.

The Conglomerate.—Although this communication mainly concerns the lavas, a few lines are necessary to describe the conglomerate which occurs immediately below them and is used as a lower limit in determining their horizon.

The best exposures are in the neighbourhood of Wood Hall, north of Cockermouth, where about 50 ft. is seen, though the total thickness is probably nearer double that amount. The formation consists of rock fragments up to 3 or 4 in. in diameter, mainly rounded but frequently subangular, set in a sandy matrix consolidated by a limy cement and often stained red. Although bedding of the coarser fragments is not apparent, posts of such material alternate with beds of coarse, buff, and occasionally flaggy sandstone, and in places with red sandy marl indistinguishable from Triassic marls. In the upper part of the formation, as seen in a stream in East Wood, 550 yds. N.E. of Wood Hall, thin bands of breccia-conglomerate alternate with red sandy marl altered to a green colour in places along the contacts and joints. Some of the rock fragments can be matched undoubtedly with the underlying formation, but others, mostly decomposed and of igneous origin, are at present unfamiliar. Pebbles of white vein quartz are fairly common, but the most important type is a red, purple, or grey quartzitic sandstone (not unlike some of those encountered in the Bunter of the Midlands) which is referred to the Latterbarrow Sandstone. Dr. Smith and Mr. Hollingworth confirm this identification. Some of the other rock fragments recall the sandy shales of the Skiddaw Slates, while another common constituent is a pinkish rhyolite. Dark rhyolite occurs sparingly. In the Wood Hall area, typical Borrowdale ashes are conspicuous by their absence, but farther to the north-east greenish tuffs occur very sparingly as pebbles. In this connexion it is interesting to recall the

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the experience of Clifton Ward[1] who found no Borrowdale rocks in the conglomerate on Mell Fell though they are common at Hutton, two miles farther east.

The conglomerate has not been found south-west of the Cockermouth-Carlisle road but appears immediately east of that road and at intervals along the north-west bank of the Derwent for several miles (Fig. 1). In addition to that in the neighbourhood of Wood Hall, the exposure in the gill below Redmain is worthy of notice, especially since the Latterbarrow Sandstone there occurs *in situ* below the conglomerate. North-east of Redmain exposures are poor, on account of Glacial drift, but the rock is again seen in the lower part of Park Wood, along Blumer Beck, about three quarters of a mile south-west of Sunderland. From that point it has not been located until the John Peel barytes mine at Ruthwaite is reached, where trial shafts, to the east of the main vein, passed through a pebbly sandstone with bands of conglomerate. It also occurs in typical form in the stream immediately south of Uldale, to the east of the road leading to Over Water. In this eastern area the conglomerate must rest on the Borrowdale rocks which crop out to the south.

The Lavas.—The lavas are usually fine-grained, dark, blue-grey compact rocks. Minute amygdales are frequently present and these are in places sufficiently large and numerous to give the rock a scoriaceous appearance, especially at the top and bottom of the flows, although in some cases the distribution of the clinker-like rock is haphazard. The vesicles are frequently filled with calcite, agate or quartz, and when the rock is markedly slaggy these are stained bright green. Although the vesicles are frequently distorted they show very little evidence of linear structure due to flow. The compact or but slightly vesicular rock is commonest in occurrence. Amygdaloidal rock is particularly well developed about a quarter of a mile north-east of Wood Hall.

The following notes on the petrological characters have been supplied by Dr. H. H. Thomas. Numbers in square brackets refer to rock slices in the Survey Collection.

"The lavas of this group are remarkably consistent, showing only slight variations in composition and structure. In their compact or less decomposed portion they are dark grey and microcrystalline, with occasional porphyritic felspars up to 1 cm. in greatest length [E.13975]. As a group they fall between micro- and macro-porphyritic basalts and by the scarcity of porphyritic felspars may be classed as a somewhat coarse variety of Dalmeny type.

"Their microscopic structure is generally that of micro-porphyritic basalt in which abundant small pseudomorphs after olivine are the dominant feature. The rest of the rock consists of granular to sub-ophitic augite and a plexus of labradorite laths that involve grains of augite and finely divided magnetite. The felspar laths frequently show a poorly developed fluxional arrangement.

[1] 'On the Physical History of the English Lake District with Notes on the Possible Subdivision of the Skiddaw Slates,' *Geol. Mag.*, 1879, p. 57. See also 'The Geology of the Northern Part of the English Lake District' (*Mem. Geol. Surv.*), 1876, p. 47.

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'Occasional porphyritic felspars of the composition of bytownite can be observed but they are rare [E.13975].

"Some of the rocks, possibly the interior of the thicker flows, have a more doleritic aspect. In these [E.13976] the augite is more definitely ophitic. In other cases, where fine-grained, the rocks might be described as tholeiites [E.13898]. They contain original glass and an abundance of chlorophaeite, a mineral common in the Carboniferous intrusions of the Lothians.

"Olivine in these lavas is abundant, generally pseudomorphed by the usual limonitic and chloritic secondary products, but occasional remnants of olivine are preserved in fresh condition [E.13898].

"The augite is quite frequently fresh but when decomposed passes into carbonates.

"Felspars do not appear to have been albitized to any considerable extent but have been involved in a general replacement by carbonates.

"As a suite they are quite unlike not only any Borrowdale volcanic rocks with which I am acquainted but also any Lower Palaeozoic rocks that I have met with. They can be matched amongst the Lower Carboniferous lavas of Fifeshire and there is no doubt that their chief likeness is to the Carboniferous lavas of Scotland and to some of the Carboniferous intrusions of the north of England."

Although the lavas form several flows, of which there are four or five near Wood Hall with an aggregate thickness of over 300 ft., no tuffs have been noticed, though it is interesting to record that a roughly lenticular mass of red and green marl or 'bole-like' material, interspersed with lumps of very rotten amygdaloidal rock, occurs between two flows in the stream north-east of Wood Hall.

Rectangular jointing is common in the compact rock but there is no development of the columnar jointing usually associated with this class of lava.

The general distribution of the lavas is shown in the sketch map (Fig. 1). The following remarks apply to particular occurrences.

To the south-west the outcrop of the lavas is terminated by a fault about half a mile east of Brigham. In this area exposures are poor owing to the presence of Glacial drift, but both the amygdaloidal and compact types may be seen between Scales, East House and the River Derwent.

North of the Derwent, drift masks the outcrop as far east as the Carlisle-Cockermouth road; but from thence to the north-east exposures are frequent and the outcrop is almost continuous, although shifted by faults. Some of the best exposures are in the vicinity of Wood Hall, just over a mile north of Cockermouth, the stream section a quarter of a mile north-east of that mansion being particularly fine. In this area the basalt is faulted against the 7th or Bottom Limestone. From Redmain to some distance beyond that hamlet, this fault probably cuts out the basalt and brings the 7th Limestone against the conglomerate, though farther to the north-east the basalt reappears whilst the conglomerate is cut out by the fault. In this part of the outcrop exposures are particularly good in the stream flowing into the Derwent from Blindcrake. Here gently dipping shales and thin limestones, which occur at the bottom of the Limestone Series, are seen within 30 ft. of the basalt.

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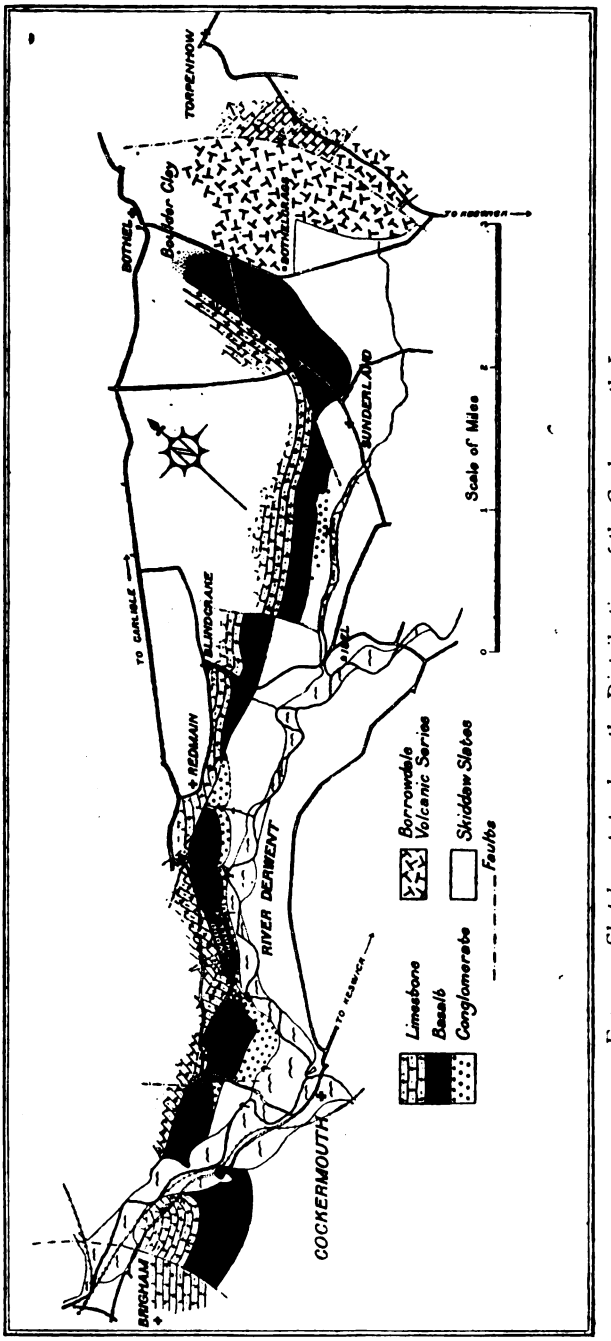

FIG. 1.—*Sketch-map to show the Distribution of the Cockermouth Lavas.*

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About half a mile east of Blindcrake the outcrop of the lavas is shifted to the south by a dip-fault, limestone on the east being brought within a few feet of exposures of basalt. Thence towards Sunderland exposures are common, the basalt ranging through Park Wood accompanied by a parallel outcrop of limestones in the higher ground; while the conglomerate and the Skiddaw Slates may be seen in or near the stream at the bottom of the wood.

About the village of Sunderland the outcrop is obscured by thick Glacial drift and there may be some faulting as the ground is locally of lower relief than one would expect from basalt; but from the Methodist Chapel to Bothelcrags there are several small quarries in the rock, which is here seldom markedly vesicular. The best quarry is that on the south-west side of the road about a quarter of a mile north-west of Bothelcrags, while a coarser variety forms a small knoll about half a mile south of Bothel.

It is evident, therefore, that the lavas can be traced with certainty from between Brigham and Cockermouth to the Bothel-Keswick road at Bothelcrags. In this stretch of ground, rocks referable to the Borrowdale Volcanic Group are absent, the conglomerate below the lavas being in contact with the Skiddaw Slates, of which the highest member is exposed in one place only, namely Redmain Gill.

In the intensively explored iron-ore field to the south-west no trace of the lavas has been found, and this was one of the reasons why hesitation was at first felt in assigning them to the Carboniferous period.

Near Bothelcrags the Keswick road may be taken as the dividing line between the Cockermouth lavas and the Borrowdale Volcanic Group, for typical andesitic Borrowdale rocks and the porphyritic Eycott types, both devoid of olivine, are exposed north-east of the road, whilst quarries in the basalt abut on the road on the south-west. Unless the lavas die out abruptly there must be a fault along the road, but the adjacent ground awaits detailed mapping. Whether faulted or not, it is a fact that traverses have failed to reveal any outcrops of the Cockermouth basalt beyond this line, and at Uldale farther east there is no room between the outcrops of the conglomerate and the Limestone Measures for any intervening basalt. We must assume, then, that the lavas either die out rather abruptly, or are overlapped, as we proceed from west to east. The latter seems the more probable.

To produce a mass of rock some 300 ft. in thickness, and cropping out over a distance of seven miles, implies more than a trifling outbreak of vulcanicity. The mode of occurrence of the basalt, as flows with slaggy tops and bottoms, precludes the idea of intrusion; while the absence of pillow structure suggests an outpouring on land. Quiet extrusion is indicated by the apparent absence of ashes, and the presence of 'bole' suggests some interval between the flows. Where the volcanic pipe or fissure was situated—and there may have been more than one—we do not know. Clifton Ward[1] records

[1] 'On the Physical History of the English Lake District, etc.,' *Geol. Mag.*, 1879, p. 58.

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small bosses of basalt penetrating the Carboniferous conglomerate near Mell Fell Farm north-west of Ullswater. In our district the only basalt dyke encountered, and that only 5 ft. in thickness, occurs in the Skiddaw Slates immediately below the conglomerate in the bank of the Derwent below Wood Hall. This is too small to account for such a large outpouring in the vicinity, but may be a dyke connected with a large concealed pipe. On the other hand, it is possible that the place of origin is now buried beneath the Solway, for it is suggestive that similar rocks to those of Cockermouth should occur in the Isle of Man[1] and along the English-Scottish Border.

Age of the Lavas.—Whilst the age of the basalt cannot be definitely settled in the absence of fossil horizons occurring immediately above and below, certain factors make it probable that we are dealing with an outbreak of vulcanicity in the earlier part of the Carboniferous sequence of this district. The limestone that occurs above, and with the same strike and order of dip as the lavas, is the Seventh Limestone of the West Cumberland sequence and belongs to S_3 horizon of Vaughan's classification.[2] The conglomerate that occurs below the basalt is almost identical in appearance with that of Mell Fell, the age of which is regarded by some observers as Carboniferous[3] while others claim it to be Old Red Sandstone.[4] The earliest possible age, on stratigraphical grounds, for our lavas, is therefore Old Red Sandstone (probably the later part), and the latest age Carboniferous Limestone (early S).

The Borrowdale lavas consist largely of rhyolites and andesites and, although some are more basic, olivine is either rare[5] or absent[6]. Our lavas on the other hand are rich in olivine and, according to Dr. Thomas, unlike older Palaeozoic lavas but very similar to Scottish lavas of Carboniferous age.

Prof. Garwood[7] has recently found a lava, identical with those of Cockermouth, near Kershope Foot, on the borders of Cumberland and Dumfriesshire. This occurs in the Limestone Series and is overlain by a limestone with *Nematophyllum minus*, a fossil characteristic of our Seventh Limestone.

The Cockermouth lavas, not only the compact type, but also the scoriaceous variety and the 'bole', may be also matched perfectly with that of Little Wenlock, Shropshire, which occurs

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[1] See 'The Geology of the Isle of Man' (*Mem. Geol. Surv.*), 1903, p. 226.

[2] See Edmonds, C., 'The Carboniferous Limestone Series of West Cumberland,' *Geol. Mag.*, 1922, pp. 74-83 and 117-131.

[3] Ward, J. Clifton, *op. cit.* See also J. E. Marr, 'The Geology of the Lake District,' *Camb. Univ. Press*, 1916, p. 113.

[4] Green, J. F. N., 'The Mell Fell Conglomerate,' *Proc. Geol. Assoc.*, vol. xxix, 1918, pp. 117-125.

[5] Ward, J. Clifton, 'The Geology of the Northern Part of the English Lake District' (*Mem. Geol. Surv.*), 1876, p. 20. See also *Monthly Microscopical Journ.*, vol. xvii, 1877, pp. 239-246.

[6] Harker, A., 'The Ancient Lavas of the English Lake District,' *The Naturalist*, 1891, p. 145; see also *Proc. Yorks. Geol. & Polytechnic Soc.*, vol. xiv, 1902, p. 487.

[7] To whom thanks are due for allowing publication of this fact.

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as a flow in beds of D_2 age and was recently described by Mr. R. W. Pocock[1].

On petrological and on stratigraphical grounds, therefore, there is every probability that the lavas cropping out between Bothel and Brigham, which we designate the 'Cockermouth Lavas', belong to the Carboniferous Limestone Series.

Vulcanicity in Other Areas.—Although hitherto unsuspected in West Cumberland, volcanic episodes in the Carboniferous Limestone sequence are of common occurrence elsewhere in Britain. In Scotland they are particularly common[2], and similar basalts to those of Cockermouth occur frequently in the Calciferous Sandstone Series[3].

Those on the English side of the Border have already been noticed, and they appear to continue through Dumfriesshire to Kirkcudbrightshire[4], and also occur in Roxburghshire.

To the south of our area the lavas[5] of Derbyshire[6] have long been known and the work of Dr. T. F. Sibly[6] shows that they belong to a D_1 horizon. Those of Shropshire [*op. cit.*] are higher in the sequence, being of D_2 age, while, continuing southwards, we come to the occurrences in the Bristol district[7] lower in the succession and occurring between the horizons Z and C.

In most cases the lavas are associated with tuffs. In West Cumberland no tuffs have been found, but farther north tuffs occur in association with the basalt in the Penton-Kershope Foot area on the English side of the Border.

The Cockermouth lavas therefore form an interesting link between the English and Scottish occurrences, and though these effusions are not confined to any one particular horizon in the Carboniferous Limestone sequence they indicate widespread vulcanicity during that period.

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[1] 'The Basalt of Little Wenlock (Shropshire),' 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, Appendix I, pp. 140-156.

[2] Geikie, A., 'The Ancient Volcanoes of Great Britain,' London, 1897, vol. ii.

[3] 'The Geology of Central and Western Fife and Kinross-shire' (*Mem. Geol. Surv.*), 1900, pp. 53, 54. See also 'The Geology of the Glasgow District' (*Mem. Geol. Surv.*), ed.2, 1925, pp. 135-149, 178.

[4] 'Explanation of Sheet 5' (*Mem. Geol. Surv.*), 1896, pp. 28-29. For those of Liddesdale see Geikie, A., *op. cit.*, vol. i, pp. 475-477. A rock similar to that of Cockermouth was described from Stichill, near Kelso, by J. J. H. Teall, 'British Petrography,' 1888, p. 197, and *Geol. Mag.*, 1883, pp. 100, 258, 260.

[5] Arnold Bemrose, H. H., 'The Toadstones of Derbyshire: their Field Relations and Petrography,' *Quart. Journ. Geol. Soc.*, vol. lxiii, 1907, pp. 241-281. See also C. B. Wedd, in 'The Geology of the Northern Part of the Derbyshire Coalfield' (*Mem. Geol. Surv.*), 1913, pp. 22-25.

[6] 'The Faunal Succession in the Carboniferous Limestone of the Midland Area,' *Quart. Journ. Geol. Soc.*, vol. lxiv, 1908, p. 39.

[7] Morgan, C. L., and S. H. Reynolds, 'The Igneous Rocks associated with the Carboniferous Limestone of the Bristol District,' *Quart. Journ. Geol. Soc.*, vol. lx, 1904, p. 137. Also S. H. Reynolds in 'Geology in the Field,' *Geol. Assoc.*, 1910, pp. 322-4; and 'Further Work on the Igneous Rocks associated with the Carboniferous Limestone of the Bristol District,' *Quart. Journ. Geol. Soc.*, vol. lxxii, 1917, p. 23.

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III.—THE ORIGIN OF CUMBERLAND HAEMATITE (1).—By E. E. L. Dixon, A.R.C.Sc., B.Sc.

Text-figure 1.

HAEMATITE-VEINS IN THE SKIDDAW SLATES

Haematite occurs in Cumberland chiefly in limestones, the ore-bodies in the Carboniferous Limestone being well-known and of great commercial importance. It is also found, however, in non-calcareous rocks, and of these occurrences the most important are the veins in the Skiddaw Slate of Kelton Fell and Knock Murton on the edge of the fells, east of Whitehaven. From these, though now practically exhausted and no longer worked, many thousand tons of ore have been raised by Messrs. Wm. Baird and Co., to whose late manager, Mr. Wm. Casson, our thanks are due for much valuable information about the surface-position and underground extent and character of the veins. In conjunction with the mapping of the various subdivisions of the Skiddaw Slate that form the country-rock, these details have revealed some of the conditions favouring ore-deposition in that formation.

In this district the Skiddaw Slate consists of the following groups in descending order[1]:—

4. Mosser Slates
3. Loweswater Flags
2. Kirkstile Slates
1. Blake Fell Mudstones

The groups of importance in the present connexion are the Kirkstile Slates and the Loweswater Flags, the former a band of soft dark slates practically devoid of sandstones, whereas the flag-group comprises innumerable alternations of hard sandstones and thin slates.

As is well known, the structure of the Skiddaw Slate of the Lake District is a great anticline complicated by much minor folding. South-west of Loweswater, however, the outcrop of the flag-group in the northern limb is comparatively simple, the beds dipping N.N.W. fairly steadily at 70° or more. Between Knock Murton and Keltonfell Top these rocks are crossed by two series of tear-faults, running approximately N.W.—S.E. and N.—S. respectively, and the fault-fissures, becoming the paths of mineralizing solutions, have given rise to the great majority of the haematite-veins. But, in places, the veins are so numerous as to suggest that under suitable conditions insignificant faults or mere joint-planes have been mineralized. The best example is afforded by the network of veins, immediately east of Keltonfell Top, that includes Veins

[1] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, pp. 70-1.

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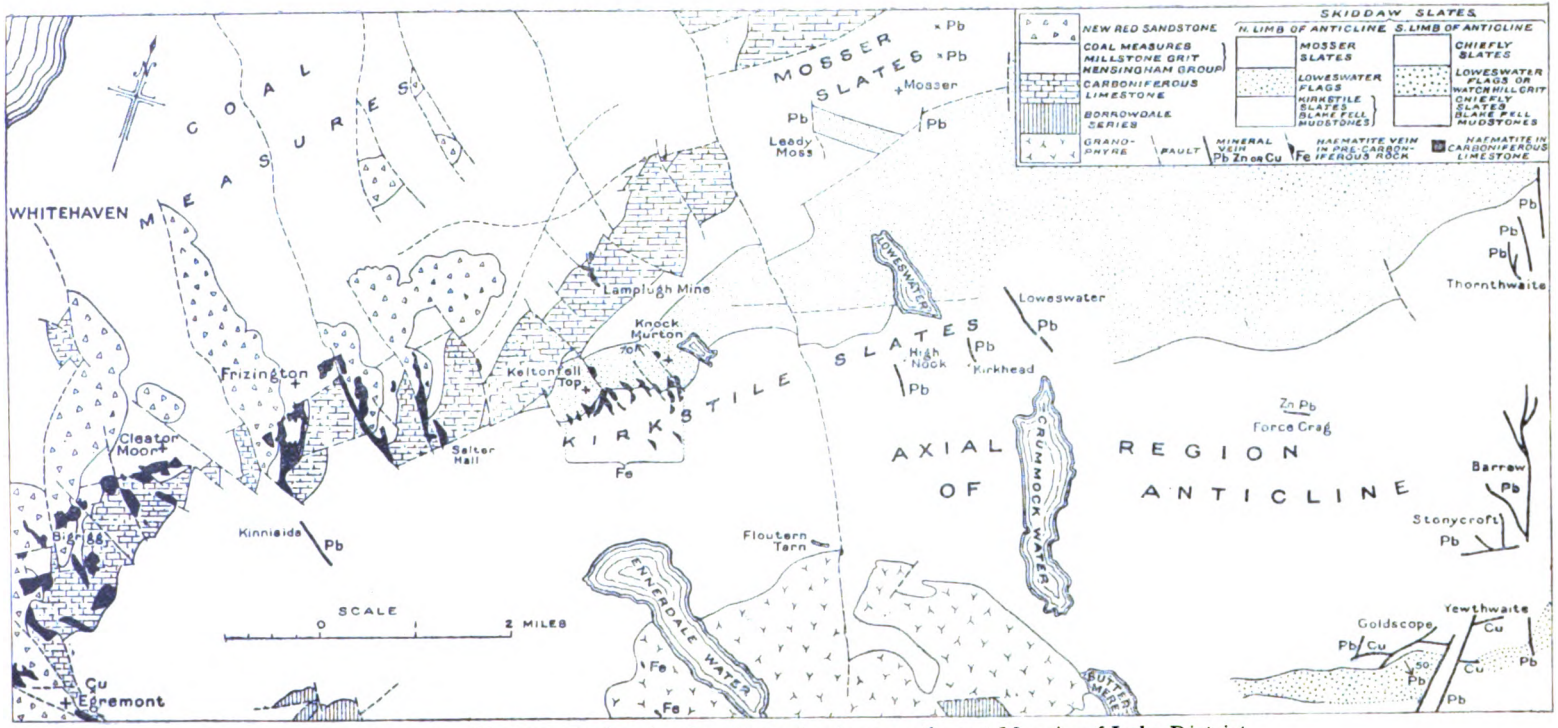

FIG. 1.—*Sketch-map showing Ore Deposits along north-west Margin of Lake District.*

The triangular area of Loweswater Flags S.W. of Loweswater should be stippled.

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1 and 2, B, D, G and H Veins, Vein North of Dyke, and the numerous splits off these veins. This view is supported by the fact, mentioned by Mr. Casson, that in several cases a vein could not be traced beyond the point where the ore thinned away and was lost, the cheeks apparently disappearing with the ore.

The ore has been deposited chiefly where the fissures cross the steeply-inclined junction of the Loweswater Flags with the Kirkstile Slates. It extends along the fissures well into the ground where the latter slates form both walls and, as a rule, to a much less extent in the opposite direction, *i.e.*, into the Loweswater Flags. On the map (Fig. 1) it will be seen that the veins are strung out along the junction; the greater development of ore in the adjacent slates than in the flags is most apparent in the above-mentioned network.

Nevertheless, it would appear that the fissures in the flags have been the channels for the mineralizing solutions, for bodies of ore have been deposited also where the two chief faults cross a band of mudstones in the upper part of the flag group, and, in many places along the outcrop in this district, joint-planes in this group have been encrusted with films of haematite or the sandstones along the planes have been permeated with the mineral.

Mineralizing solutions, whether ascending or descending, would be expected to follow the more open channels, as those in the flags may be presumed to have been, and instances of their behaviour in this way are well known[1]. Ore-deposition at or near a junction of dissimilar rocks also is a matter of common observation. Its significance in the present case is that when the outcrop of the Loweswater Flags is followed north-north-eastward from Knock Murton to Loweswater and Mosser the haematite-veins are lost, but a few small lead-veins appear in the slates not far below or above the Loweswater Flags or at the upper boundary of the flags. Within the limits of the ground re-surveyed in detail these veins are too few and small to be anything but suggestive. Traverses through the ground to the east as far as the Derwent valley (north-eastern edge of Fig. 1) show, however, that in the northern limb of the Skiddaw Slate anticline all the worked veins of lead and zinc occur near the junction of the Loweswater Flags with the underlying slates, and that in the southern limb the veins of copper and lead that have been worked at Goldscope, Yewthwaite and Brandlehow are similarly placed as regards a sandstone group that is either the Loweswater Flags or the Watch Hill Grit (a band in the Mosser Slates). Further, the Castlenook lead-mine lies near the top of the southern sandstone group. The country-rock of the remaining group of veins, those at Barrow and Stonycroft, has not been examined.

The outcrops of the non-ferrous veins are shown in Fig. 1 and

[1] *Cf.*, for example, the lead-zinc veins of the Minsterley district, described by Mr. T. C. F. Hall (see 'Special Reports on the Mineral Resources of Great Britain' (*Mem. Geol. Surv.*), vol. xxiii (Lead and Zinc Ores in the Pre-Carboniferous Rocks of West Shropshire and North Wales), 1922, and *Mining Mag.*, vol. xxvii, 1922, pp. 201-9). Usually, as in this instance, the ore occurs in the fissured rock, not in the adjacent argillaceous beds.

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have been taken from the Geological Survey maps and memoir[1]; the position of the sandstone group north-east of Goldscope is uncertain and the base is indicated by a dotted line.

The channels of the iron solutions through the Skiddaw Slate were similar, then, to those of the lead, zinc and copper solutions, and haematite was deposited not far beyond the limit of deposition of galena.[2]

As to the nature of these solutions, whether of lead, zinc and copper or of iron, conflicting views have long been, and still are, held. According to one theory the metallic compounds have been conveyed to their present position from overlying or possibly surrounding rocks, or from a continental drainage-basin, by descending meteoric waters. On the other view, their origin is magmatic and either deep-seated or volcanic, the transporting agent being ascending waters.

As regards the non-ferrous ores, the magmatic theory, though by no means universally held, is gaining ground,[3] but in the case of the haematite-veins it has received little favour, opinion being dominated by conclusions based on the ore-bodies in the Carboniferous Limestone, which are the best known and are by far the most important economically. Of these bodies it has been established beyond question that many have been deposited by downward-percolating waters, a fact which, taken in conjunction with the presence of a great thickness of red beds above and the general tendency of formations, unconformably overlain by such beds, themselves to be reddened from above, seemingly makes it unnecessary to look elsewhere than in the red beds for the source of the iron. Nevertheless, as Dr. B. Smith has shown[4], the explanation in the form that would make the period of ore-deposition earlier than, or contemporaneous with, that of the New Red Sandstone encounters great difficulties. But a great obstacle to all theories of downward percolation is that they fail to account for the occurrence of workable veins of haematite to considerable depths in Skiddaw Slate and other non-calcareous rocks. Owing to their restricted occurrence compared with that of the ore-bodies in the Carboniferous Limestone these veins have received little attention outside the district, but their importance in this connexion has been pointed out by J. D. Kendall, who in 1879 first suggested the deposition of the Cumberland haematites by magmatic waters[5] and has maintained it on many

[1] Eastwood, T., 'Special Reports on the Mineral Resources of Great Britain' (*Mem. Geol. Surv.*), vol. xxii (The Lead and Zinc Ores of the Lake District), 1921.

[2] The occurrence of a lead-vein at Kinniside (mapped, like the haematite-veins in the granophyre, by Mr. Hollingworth) and of copper near Egremont shows that the geographical distribution of the various metals is not simple, but does not negative the general truth of the statement.

[3] As it would appear, following two papers by A. M. Finlayson, 'The Metallogeny of the British Isles,' *Quart. Journ. Geol. Soc.*, vol. lxvi, 1910, pp. 281-98, and 'Ore-Deposition in the Lead and Zinc Veins of Great Britain,' *op. cit.*, pp. 299-328.

[4] 'Special Reports on the Mineral Resources of Great Britain' (*Mem. Geol. Surv.*), vol. viii (Haematites of West Cumberland, Lancashire and the Lake District), ed. 2, 1924, p. 40. This important work will be referred to as 'the memoir.'

[5] 'The Haematite Deposits of West Cumberland,' *Trans. N. Eng. Inst. Min. & Mech. Eng.*, vol. xxviii, 1879, pp. 109-54.

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later occasions[1]. The importance of the veins is emphasized by the more recent developments on them, and it would seem that the following facts are irreconcilable with deposition by descending meteoric waters. A few of the veins have been workable to depths of 600 ft., wholly in Skiddaw Slate, at which level Keltonfell No. 2 Vein is locally 10 ft. wide at a junction with a branch-vein. At less depths thicknesses of 20 ft. of ore were occasionally found in several veins, and in the case of H Vein the ore, even where of this thickness, was mixed with little slate. It is difficult to suppose that any meteoric water that percolates along small faults or mere joint-planes in the soft Kirkstile Slates at the greater depths has much power of replacement. Nevertheless, it would appear, from an examination of many specimens of impure ore taken from the dumps, that the haematite actually replaces the Skiddaw Slate. For, besides lining fissures and filling cavities between fragments of slate and sandstone, it has every appearance of replacing fault-breccia of either kind of rock by a process of spreading through the comminuted interstitial material first and of attacking the larger fragments along innumerable veinlets. Kendall also has concluded,[2] from a study of the workings of his time, that the haematite replaces the country-rock. The replacement appears, however, to have been direct and not to have followed an earlier replacement by dolomite, as suggested by him in one of his later writings.[3]

This evidence outweighs the few facts pertaining to the haematite veins in the Skiddaw Slate that have been, or may be, held to militate against a magmatic origin. Thus, the veins thin away downward, but this is not necessarily an indication of deposition from above, as downward impoverishment is also shown by mineral veins of undoubted magmatic origin in many parts of the world.

The remarkable purity of the average run of ore, to which it owes its value in metallurgy, may also possibly be urged against the magmatic theory. On the other hand, it may be that the abundance of crystals of specular iron of medium or large size is a sufficient indication of a magmatic origin. Such crystals are frequent in pneumatolytic deposits, but appear to be unknown in those of ordinary meteoric waters. Were they formed by such waters, even at considerable depths only, they would be expected in the deeper parts of some gossans in arid countries or in some veins in red beds under conditions precluding pneumatolytic action.

Again, it is unusual for fairly deep-seated iron ores of magmatic origin to consist of haematite to the exclusion of magnetite. The former, apparently without the latter, is, however, abundant in some tin-veins in the Dartmoor granite[4] that are undoubtedly

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[1] See *Mining Mag.*, vol. 32, 1925, p. 137. A magmatic theory has also been advanced by W. McDonald ('West Cumberland Hematite Deposits,' *Iron & Coal Trades Review*, vol. 110, 1925, p. 434).

[2] 'The Haematite Deposits of West Cumberland,' *op. cit.*, pp. 43-4 (of separate).

[3] 'The Iron Ores of Great Britain and Ireland,' 1893, p. 311.

[4] MacAlister, D. A., 'Note on the Association of Cassiterite and Specular Iron in the Lodes of Dartmoor,' *Geol. Mag.*, 1909, pp. 402-9.

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magmatic. It would appear, too, that the argument might be used equally against the meteoric theory.

The hypothesis that both the haematite and the non-ferrous veins in the Skiddaw Slates have been deposited by magmatic waters affords a ready explanation of the similarity of their relations to the country-rock. The fact that the haematite-veins have been deposited not far beyond the limit of deposition of galena may be purely a coincidence, but it is suggestive of a genetic connexion that in Cornwall the lead metallogenetic zone is succeeded by one of iron-ores.[1] It should be added, however, that these ores include not only haematite but also the ferrous compound, chalybite, which is absent from the haematite-veins in the Skiddaw Slates. Also in Cornwall the zones are ' telescoped ' and overlap one another, whereas most of the haematite-veins in the Skiddaw Slate have been bottomed and no lead or other non-ferrous ores, except manganese, are present in any, and the workable veins form a group separated from the nearest lead-veins by barren ground.

It has already been suggested by Kendall,[2] from the facts of areal distribution, that the haematite-deposits constitute a zone beyond that of the lead-ores. The later work on the Skiddaw Slates and their contained veins, outlined above, shows that the relationship of haematite to lead-ore is possibly much closer than has hitherto been suspected. In the same paper he concludes that the emission of haematite-depositing solutions in Cumberland and Lancashire has been partly determined by anticlinal axes in the Skiddaw Slates. So far as the area illustrated by Fig. 1 is concerned, the view now suggested differs from Kendall's only in attributing importance (as affording channels for the emission) also to a sandstone group, the Loweswater Flags, in the Skiddaw Slates.

THE HAEMATITE IN THE CARBONIFEROUS LIMESTONE

General Distribution in the Whitehaven District.—To what extent is the magmatic hypothesis negatived or confirmed by facts relating to the haematite ore-bodies in the Carboniferous Limestone ?

The map[3] shows the distribution of haematite in the Whitehaven district in both limestone and Skiddaw Slate as well as the inter-relations of the two formations. It is seen that south-west of Keltonfell Top the Loweswater Flags are rapidly overstepped by the Carboniferous Limestone, but maintain their strike, in the old platform on which the limestone rests, south-westward as far at least as Frizington. With the exception of that at Lamplugh, close by, ore-bodies are unknown in the limestone for many miles north-east of the region of overlap, but to the south-west they appear in force in a

[1] Davison, E. H., ' The Primary Zones of Cornish Lodes,' *Geol. Mag.*, 1921, pp. 505-12, and *Econ. Geol.*, vol. xxii, 1927, pp. 475-9 ; H. B. Cronshaw, ' The Structure and Genesis of some Tin Lodes occurring in the Camborne District of West Cornwall,' *Trans. Inst. Min. Met.*, vol. xxx, 1921, pp. 408-49 ; H. Dewey, ' The Mineral Zones of Cornwall,' *Proc. Geol. Assoc.*, vol. xxxvi, 1925, pp. 107-35.

[2] ' Lateral Distribution of Metallic Minerals,' *Mining Mag.*, vol. xxiii, 1920, pp. 75-80.

[3] The positions of the known ore-bodies in the limestone are taken from Pl. I of Dr. Smith's memoir with slight additions from Kendall's plan of the huge Parkside ' flat ' near Frizington (' The Haematite Deposits of West Cumberland,' *op. cit.*, Pl. XXV, fig. 3) and from other mining information (Frizington to Lamplugh).

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distance of about a mile (at Salter Hall) and continue thence without marked interruption to the Florence, Ullcoats and Winscales mines a short distance beyond Egremont, where the limestone is overstepped by the New Red Sandstone. Their appearance close to where the Loweswater Flags pass below the limestone may be a coincidence, but it is clear that if, as suggested, the flag-group has been the path of ascending ferruginous solutions, they would be expected in the overlying limestone where they actually occur.

The flags may well continue south-westward beneath the Carboniferous Limestone as far as Bigrigg, but between that place and Egremont other beds in the Skiddaw Slates, and also Borrowdale rocks, enter the pre-Carboniferous platform. As the ore-bodies in the overlying limestone persist beyond Bigrigg to the termination of the limestone near Egremont, it is evident that those south-east of Bigrigg have not originated directly from solutions arising through the Loweswater Flags. We shall presently see, however, that these ore-bodies differ essentially, in their relations to the geological structure, from those north-east of Bigrigg.

Relations to Geographical Structure.—As regards these relations the most important fact, the close connexion between ore-deposition and faults, is equally explicable on either view of the origin of the ore. It is from the relations of ore-bodies to the base of the limestone (or to older rocks against which the limestone is faulted) that the theory of descending solutions derives its strength. The evidence has been clearly stated and illustrated by Dr. Smith[1], and cannot be gainsaid. In places " the ore lies on the foot-wall of the fault (Skiddaw Slate) and sends out extensions as flats " along the base of the limestone, or it rests on an impermeable shale below a bed of limestone, such as the Fourth Shale (see figs. 11 and 13). If the relations of the ore were similar throughout the field there could be no further question as to the direction of movement of all the solutions. But, as mentioned by Dr. Smith, the ore is found as flats at the base of the limestone only between Egremont and Bigrigg (that is, along that part of its course where the limestone is overlain by the New Red Sandstone directly), and at The Flosh and probably Todholes, along the outcrop of the limestone south of Cleator Moor[2]. At Bigrigg and to the north-east, where impermeable beds (Hensingham Group and higher strata) overlie the limestone, the relations of the ore show a marked change. Not only are the flats at the base lost, but bodies " tend to cluster some distance above the base of the series ". From Bigrigg to Winder, near Salter Hall, replacement of the limestone immediately underlying the Hensingham Group is of frequent occurrence.[3]

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[1] *Op. cit.*, p. 36 and, *e.g.*, figs. 5-7 and Pl. V.

[2] Kendall states that " in the north-eastern part of the district iron ore has only been worked in the bottom beds at Parkside " (' The Distribution of Ore in Depth,' *Mining Mag.*, vol. 22, 1920, pp. 282-6, fig. 2 ; see also *Mining Mag.*, vol. 32, 1925, p. 144, fig. 6).

[3] See Figs. 9, 11 and 18 of the memoir. The known ore-bodies in the two parts of the field are contrasted in figs. 2-4 of Kendall's paper ' The Distribution of Ore in Depth.'

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Although, as mentioned in the memoir (from which the quotation above is made), the cover of impermeable beds would cut off descending solutions (and, possibly, by introducing artesian conditions, it may have changed the underground circulation to such an extent that water passed freely along the highest limestone but not along the lowest), the distribution of ore at Bigrigg and to the north-east is at least as readily explicable if it be supposed that along this tract iron solutions have risen along fault-fissures through the limestone and spread here and there beneath one or other of the relatively impermeable shales and sandstones that split up the limestone-mass or overlie it. For in places, as in the case of the 'flat' at the top of a bed of limestone (the Fifth Limestone) at Lamplugh Mine, the ore follows the under surface of a relatively impermeable bed (at Lamplugh a compact sandstone) in the mass of the limestone and is underlain by unaltered limestone. In some localities, *e.g.*, the part of Bigrigg illustrated by fig. 11 of the memoir, one ore-body may underlie one impermeable bed and another may overlie a second. Varying relations of this kind would result in those places where, at different times, ascending magmatic and descending meteoric waters varied in relative influence, and would be expected near the edge of the Hensingham Group cover, as at Bigrigg, or might be found locally beneath the cover itself.

Near Bigrigg, at the basset-edge of the cover, descending meteoric waters would be likely to meet the ascending solutions and, carrying them down through the limestone, could account for the ore-bodies at the base of the limestone to the south-east. But near Winscales, at least, there may well have been a source of ascending solutions independent of any in the Loweswater Flags.

The difference between the north-eastern part of the iron-ore field and the south-eastern end as regards ore-bodies at the base of the limestone is discussed also by Kendall[1], who suggests as the most probable answer that the beds in the north-eastern part have never been bored at the proper place. Be this as it may, the known general distribution of the ore-bodies throughout the limestone may be equally explicable whether the solutions be regarded as everywhere descending or as largely ascending beneath the cover of impermeable rocks and descending where this is absent.

Before leaving this part of the question it should be added that a bed of haematite, probably altered *Spirorbis*-limestone[2], in the Whitehaven Sandstone at Millyeat, near Frizington, seems at first sight to be attributable solely to waters descending from New Red Sandstone, for brockram at the base of the latter crops out at a short distance, whereas the top of the Carboniferous Limestone probably lies more than 1,000 ft. below. If alteration of limestone close below brockram to haematite were at all general, the argument would be unanswerable, but as a fact it is seen from figs. 3-6 and Pl. V of the memoir that limestone in this position, even in the proximity of

[1] 'The Distribution of Ore in Depth,' *op. cit.*
[2] Kendall, J. D., 'The Iron Ores of Great Britain and Ireland,' 1893, pp. 117-9.

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faults, is no more frequently altered than other limestone. The association at Millyeat may therefore be accidental, and a N.N.W. fault, like those that often carry ore in the Carboniferous Limestone, which crosses the brockram, is a possible path of the ferruginous solutions.

Associated Minerals.—The mineral associates of the haematite in the Carboniferous Limestone and the changes they have undergone suggest a magmatic origin rather than deposition by meteoric waters.

As evidence against a magmatic origin may again be urged the remarkable freedom of the haematite from other ores except, in places, those of manganese. Exceptionally a little copper pyrites is associated with haematite at Eskett (near Salter Hall) and galena has been found by Dr. Smith in the limestone at Parkside. The chief gangue minerals, calcite, dolomite, quartz and barytes, afford no criterion. On the other hand fluor, one of the most characteristic deposits of acid magmatic solutions, is present, though in its rarity it contrasts with that in magmatic veins of many places, such as Alston Moor and Derbyshire. But it is less rare than in the lead and zinc veins in the Skiddaw Slate[1], for it has been found at several places and at Florence Pit and Ullcoats is occasionally abundant. Its discovery at these two mines is due to Dr. L. J. Spencer, to whom I am indebted for allowing me to examine his material and publish the following details.

The crystals are generally colourless or, in a few cases, with a red central or outer zone. They are among the latest minerals lining the cavities ('loughs'), the sequence of these last deposits being :— kidney ore and specular iron, quartz, fluor,—at this stage in places interruption by fracturing,—barytes, dolomite, and finally marcasite (occasional), or, after the quartz and fluor, no later mineral or only a light dusting of small crystals of specular iron.

Fluor has also been found at Bigrigg (several mines[2], at Langhorn quarry[3] in the top limestone, and not uncommonly at Fletcher Pit[4]), Cleator Moor[5], old Parkside Mine (not uncommon)[3], and at Kelton quarry in the top limestone. Outside the Whitehaven iron-ore field it occurs lining a joint[6] in Skiddaw Slate half a mile north-east of the Kinniside lead-vein, and has been found in the haematite-mines to the south at Hodbarrow[7] and, replaced by haematite, in Furness.[8]

Although, in general, the powers of replacement of the ferruginous solutions that have deposited the ore-bodies in the Carboniferous Limestone have been feeble, in places they have been considerable

[1] Eastwood, T., *op. cit.*, p. 3.
[2] Information from Mr. J. D. Kendall and Mr. Chas. Edmonds.
[3] Information from Mr. Edmonds.
[4] Kendall, J. D., 'The Iron Ores of Great Britain and Ireland,' 1803, p. 117.
[5] Greg, R. P., and W. G. Lettsom ('Manual of the Mineralogy of Great Britain and Ireland,' 1858, p. 23) and information from Mr. Edmonds (Crowgarth Mine). I have to thank Dr. Spencer for the reference.
[6] Information from Mr. S. E. Hollingworth.
[7] Information from Mr. T. C. F. Hall.
[8] Collections in the Museum of Practical Geology and the Natural History Museum.

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and unusual in character. Under normal conditions of weathering fluor and barytes are stable and practically insoluble. Yet, during the period of deposition of the haematite, crystals of both these minerals were replaced, molecule by molecule, by haematite[1] either directly or, in some cases of fluor described by Miers[2], following a temporary replacement by quartz. And from dump-material it is clear that fairly frequently a growth of haematite has enclosed an earlier deposit of barytes which, later, has been completely removed, in some cases at least within the period of haematite-deposition, as is evidenced by crusts of specular iron in the cavities left by the barytes. That the solution of the barytes has not been the work of meteoric waters through the ages is suggested by the facts that it has seldom, if ever, been partial, and, especially, that it is not unusual for dolomite- or calcite-crystals enclosing the barytes to be left untouched by the solvent.

CONCLUSIONS

1. The veins of haematite, and most of those of lead, zinc and copper ores, in the Skiddaw Slate west of the Derwent valley have been deposited near the junction of the Loweswater Flags (or a similar sandstone-group) with underlying slates, and the main channels for the passage of the metallic solutions have been fault-fissures in the sandstones.

2. Apart possibly from the purity of the ore the facts relating to the haematite-veins suggest deposition by magmatic, not meteoric, waters.

3. These veins may constitute an iron metallogenetic zone, outside one formed by the lead-veins.

4. Ore-bodies of haematite appear in the Carboniferous Limestone of the Whitehaven district where it oversteps the Loweswater Flags.

5. The relations of these ore-bodies to geological structure are consistent with deposition either by ascending magmatic waters where the limestone has an impermeable cover and by descending mixed waters elsewhere, or wholly by descending meteoric waters.

6. The abundance of specular iron, the association of haematite with fluor, rare on the whole but not uncommon in a few places, and the locally intense and abnormal chemical activity of the mineralizing solutions suggest a magmatic, not a sedimentary, origin for the ore-bodies in the Carboniferous Limestone.

7. The general body of evidence relating to the Cumberland haematites therefore, favours the magmatic theory.

8. The association of haematite with red beds in this district would appear to be accidental, not genetic.

The theory of the deposition of haematite by waters from the New Red Sandstone owes its general acceptance partly to the the co-occurrence of haematite with such rocks not only in Cumberland and Furness, but also in North and South Wales.[3] The evidence in each district should be re-examined on its merits. For instance, the replacement of Pennant Sandstone by haematite in the Forest of Dean[4] might, as a result, not be so anomalous as appears at present.

[1] Rudler, F. W., 'A Handbook to a Collection of the Minerals in the British Isles,' (*Mem. Geol. Surv.*), 1905, p. 147.

[2] 'Some British Pseudomorphs,' *Min. Mag.*, vol. xi, 1897, p. 269.

[3] See, e.g., Smith, B., *op. cit.*, p. 40.

[4] Sibly, T. F., 'Special Reports on the Mineral Resources of Great Britain' (*Mem. Geol. Surv.*), vol. x (the Haematites of the Forest of Dean and South Wales), ed. 2, 1927, p. 1.

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(2).—By Bernard Smith, M.A., Sc.D.

In attributing the origin of the haematite in West Cumberland to a magmatic source Mr. Dixon raises once more the question whether the iron-bearing solutions which effected metasomatic alteration of the rocks descended from above or ascended from below.

Mr. J. D. Kendall, who spent many years in studying the haematite deposits of West Cumberland and Furness, was a protagonist of the magmatic theory. To him we are indebted for convincing arguments in favour of the metasomatic alteration of the Carboniferous Limestone to haematite—a conclusion with which both Mr. Dixon and the writer[1] are in agreement. Mr. Kendall, however, stated that the alteration took place at a date preceding the deposition of the 'Permian' breccia which forms the base of the New Red Series. The writer showed that the date was much later, namely after the accumulation and consolidation of most, if not all, of the Triassic rocks[2]; and it may even have been Tertiary.[3]

Furthermore, the latter argued that the ore in the Carboniferous Limestone, at least, must have been formed by solutions descending from above[4]—without prejudice as to their composition or original derivation. Mr. Dixon accepts this fact of descent for part of the area only, maintaining that the waters were magmatic in origin and that many of the deposits are due to rise of solutions from below and direct attack upon the country rock, whether slate or limestone.

In the search for light upon the origin of the ore and the source of the mineralising solutions no avenue should be left unexplored, yet Mr. Dixon's theory challenges comment, for many of the points raised seem to be inconclusive or may be satisfied by alternative arguments, and some of the conclusions possess a wide implication.

The chief weakness of his case is that no satisfactory evidence is advanced in proof of the contention that the haematite-manganese veins and the other metallic veins (lead, zinc and copper) of the Lake District are of the same approximate date, or have even been derived from the same magmatic source. That both types occur at or near the junction of grits and shales is no argument for a common date, as earth movements likely to rupture the rocks at such points have occurred at various times in Lake District history. Moreover, some of the veins appear to occur outside such locations (Fig. 1, p. 24), and the influence exerted by the Loweswater Flags, as channels for movements of waters, must be extended to the Ennerdale Granophyre and the Borrowdale Volcanics also.

Except for the occurrence of the haematite in vein-like form, there is little resemblance between such 'veins' in the Skiddaw Slates and veins of recognized magmatic origin in the south-west of England. The one group is largely metasomatic, the other fills fissures.

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[1] Smith, Bernard, 'Special Reports on the Mineral Resources of Great Britain' (*Mem. Geol. Surv.*), vol. viii (Iron Ores:—Haematites of West Cumberland, Lancashire and the Lake District), ed. 2, 1924, p. 37.

[2] *Op. cit.*, p. 40.

[3] *Op. cit.*, footnote, p. 40.

[4] *Op. cit.*, pp. 38-9.

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No haematite, on the one hand, has been found in the lead, zinc and copper veins of the Lower Palaeozoic rocks of the Lake District. On the other hand, barytes, fluorspar, copper, lead or zinc are wanting in the haematite veins in the Skiddaw Slates, where Mr. Dixon claims that the waters ascended: even in the absence of the non-ferrous metals one might have expected the presence of either barytes or fluorspar, especially as they occur associated with haematite in the Carboniferous Limestone not far away and are appealed to as evidence for the magmatic origin of the ore. No evidence, however, has been adduced to prove that these two minerals, which occur in the limestone, both in association with haematite and beyond its limits, did not precede by a long interval the formation of haematite. The writer is convinced that the copper vein at Anty Cross Mine, Furness,[1] was in existence before it was invaded by the iron-bearing solutions.

Finally, if the non-ferrous mineral veins of the Lake District were formed in some late- or post-Triassic period, one would expect to find occurrences of these minerals in recognisable veins in the circuit of Triassic rocks surrounding the district.

In considering the general distribution of the ore the absence of workable veins of haematite in the Lower Palaeozoic rocks contiguous to the large deposits of ore in the limestone near Egremont and Millom, and in Low Furness—all regions in which there is evidence of downward percolation—militates strongly against the theory of direct ascent from below, or even direct ascent and subsequent descent at the places concerned. On the other hand—in favour of the downward percolation theory[1]—haematite seems to be most strongly represented in those areas fringing the pre-Permian hills where the New Red deposits can be shown to have been stepping across the Carboniferous rocks, and where they occurred either upon, or fairly close above, the Limestone itself. North of Lamplugh it is evident that a thick cover of the Hensingham Group, Millstone Grit and Coal Measures supervened between the Limestone and the New Red rocks, and here we find little or no ore; but farther round the north side of the Lake District, east of Wigton, ore appears again in the Carboniferous rocks underlying the New Red; but dies out in depth.

It must be remembered that a drainage system was operative in the Carboniferous Limestone in early Permian times, and its effects may have had considerable influence upon the anomalous positions, high or low in a bed of limestone, of certain ore-bodies formed later on. As in the Forest of Dean, also, certain beds would be more susceptible to alteration than others.

The mechanical action of "ascending magmatic and descending meteoric waters varying in relative influence" is rather difficult to understand, and it would be a strange coincidence if the solutions

[1] *Op. cit.*, p. 178.
[2] *Op. cit.*, pp. 38-43, 55, 60, 61.

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only ascended where there was a cover of impermeable rocks and descended where that cover was absent. In this connexion it should be noted that the New Red cover is considered by Mr. Dixon to be permeable. Actually the breccia with its shaly layers and the shales at the base of the St. Bees Sandstone, where unfaulted, would have acted as a fairly efficient impermeable cover; whilst the Hensingham Group and possibly Coal Measures, if faulted, might have allowed the passage of waters either way—witness Mr. Dixon's suggested explanation of the occurrence of the Millyeat ore.

This suggested upward and downward movement—an upward movement of magmatic waters highly charged with minerals, and a downward movement of the same diluted and cooled by meteoric waters—should have given rise, one would think, to some differences in their relative effects upon the limestone; yet as far as can be judged, the haematite and its associated minerals are the same in both of the type areas. Fluorspar occurs sparingly in each, yet in the accepted area of downward percolation, south of Bigrigg, the fluorine-bearing solutions would have been so diluted that separation out in loughs in recognisable form would hardly have been possible. Had the crystals been formed, however, by solution of fluorspar deposited at an earlier date and subsequent reformation their occurrence in fair quantity is understandable.

The iron-bearing waters, whatever their direction of attack, were obviously fairly potent at times, although we know little of their actual composition; yet they need not necessarily, have been magmatic. Waters in the Lower Tertiary of Knockmill in Kent[1], which certainly are not magmatic, are capable of dissolving the colloidal silica from chalk flints. In the Sandgate Beds of the Lower Greensand near Godalming[2], spiculiferous cherts are being replaced to-day by hydrous oxides of iron, including goethite. Again, barytes is being dissolved and pseudomorphed by chemical changes now taking place in the veins of the Leadhills and Wanlockhead district[3]. It is therefore possible that fluorspar formed in the limestone at a date previous to haematitisation may have been replaced by solutions or reactions which were non-magmatic in origin. Whatever their source, however, the solutions could not be described as ordinary meteoric waters.

If we consider the matter in its wider implications, despite the suggestion that the evidence in North and South Wales and the Forest of Dean should be re-examined on its merits, one cannot but recognise that if Mr. Dixon's theory is correct these other occurrences of hydrated haematites must be similarly explicable, and one would then have an iron metallogenetic province of late-

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[1] Information from Mr. H. Dewey.
[2] Information from Mr. F. H. Edmunds.
[3] 'Special Reports on the Mineral Resources of Great Britain' (*Mem. Geol. Surv.*), vol. xvii (The Lead, Zinc, Copper and Nickel Ores of Scotland), 1921, pp. 20-21.

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or post-Triassic age extending from the English Channel[1] into South Scotland. In practically all the areas where haematite occurs Triassic rocks are either directly overhead or in the near vicinity.

The above criticisms, which do not cover the whole ground, are advanced in the hope that two partially opposed points of view may lead to further light. As the matter stands the writer considers that a direct attack of solutions on the Carboniferous Limestone from below is not yet proved; and whilst, conceivably, there may have been some such action in the Skiddaw Slates, this also, in so far as it rests very largely upon the supposed relationship of the ferrous to the non-ferrous veins of the Lake District, is open to doubt.

[1] Haematite occurs in Mid-Devonian Limestones (again close beneath Triassic cover and under conditions resembling those of the Furness 'sops') at Sharkham Point, Brixham Devon, far removed from the usual metallic lodes.

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IV.—THE STRATIGRAPHICAL POSITION OF THE MANCHESTER COAL MEASURES

By LAURANCE H. TONKS, M.Sc.

Text-figures 1 and 2.

Among the problems that have arisen from time to time in the Lancashire coalfield none perhaps has led to such general confusion as the question of the true position of the measures exposed and proved at Manchester. Stratigraphical considerations and comparisons of pit-shaft records led the writer to the same correlation by grouping of coals that Professor G. Hickling has given in his later publications.[1] The numerous approximations involved in these methods, however, make such correlations articles of belief rather than of knowledge, and in this instance the inference to be drawn regarding the stratigraphical succession is of such fundamental importance that definite proof is desirable. Through the courtesy of the owners of the Bradford and Moston collieries, who permitted a detailed examination of their tunnel sections, such proof has been attained. It was realised that if the correlation was correct the marine band which occurs 200 yards above the Sod (Pottery) Mine at Dukinfield [2] would be found in the tunnel sections available. Confirmation was also to be expected from a comparison of the faunas of the musselbands in such portions of the two sections as afforded an overlap of strata. These anticipations were more than realised.

The measures from the Parker [3] to the Deep Mine at Bradford were examined in the return airway, which runs from the Deep Mine levels to the bottom of the Parker shaft. At Moston, the two main roads which are called the Platt and Hardman tunnels, have given a section from the Platt Mine to a distance of nearly 500 ft. above the Colonel. Another tunnel extends this section downwards from the Platt to the Black Mine. The beds exposed in the tunnels were examined, their lithological characters noted, and the fossiliferous horizons located. These fossiliferous bands were investigated underground only in so far as was necessary for the determination of their character and thickness. The colliery management then arranged for the getting of a tub (or tubs) of material from each band, which, after being numbered, were sent to the surface. The actual collecting of fossils was done at the pit-head, and it is difficult to see how it could have been done efficiently underground, so that in this and other ways, the free and friendly assistance of Mr. Fisher, manager at Bradford, and Mr. Richford,

[1] Explanatory Notes to the Contour Map of the Trencherbone Seam, 1924. 'Sections of Strata of the Coal Measures of Lancashire,' 1927.

[2] Lloyd, W., 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 62.

[3] For the general horizon of these measures see Figs. 1 & 2.

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manager at Moston, removed many difficulties. To them, and to the companies concerned, very sincere thanks are offered.

The vertical sections constructed from the observations made in the tunnels are given in Fig. 1. It will be seen that a detailed examination of the sequence from the Black to the Parker Mines has been made, and the fossils from some twenty *Carbonicola* bands, many of which are recorded for the first time, have been collected. At this early stage it is not possible to use specific names or descriptions with safety. Certain broad statements can, however, be made.[1] Specimens of *Anthracomya* are rare, those of *Naiadites* more common, but both these genera are subordinate in most bands to *Carbonicola*, which occurs in profusion. *Anthracomya* and *Naiadites* occur most frequently in black shale and mudstone: *Carbonicola* in grey mudstone. Complete and uncrushed specimens are of comparatively frequent occurrence. Bands of ironstone and limestone crowded with *Carbonicola* are common. These '*Carbonicola* limestones' are exasperating and unsatisfactory, for, of all the numberless fossils visible in the rock, it is but rarely that one good specimen can be obtained. Some of the bands show marked lithological characters, such as cone-in-cone ironstones, felted mudstones and the like, which may prove to be additional aids in correlation. Distinctive palaeontological character has already been observed in certain bands. The Stubbs Mine horizon (MC 9), for example, is characterised by a rich fauna with certain definite and restricted forms. It is thought that the group of coals with plant-bearing roofs which are followed by the bands MC 1 and 2 may be recognisable elsewhere. Again, the Foxholes-Colonel Mine belt is noteworthy. The grey mudstones overlying the Foxholes and Colonel Mines are crowded with beautifully preserved plant remains. The Roger roof is barren, and below the Roger occur two thin but well defined beds of *Carbonicola* limestone.

On the other hand, the band above the Platt Mine (MC 0) was disappointing in the tunnel section at Moston. The Platt Mine has been correlated with the Blenfire, but it seems more likely that at Moston the Blenfire is washed out by the massive Blenfire Rock, as it is known to be in some other localities, and that the Platt is on or about the position of the Great Mine of Oldham. On Oldham Edge a thick *Carbonicola* bed occurs between the Great Mine and the Blenfire. This bed is remarkable for the abundance and variety of the forms that occur in it. It was expected that the presence and position of this band in the tunnel would afford incontrovertible evidence of the true position of the Platt Mine, but although species of *Carbonicola* were found in hard black shale of some thickness between the Platt Mine and the base of the Blenfire Rock, they were scarce and unvaried in form in comparison with the band of Oldham Edge, even allowing for the difficulty of collecting from this type of shale in its unweathered condition.

[1] The specimens collected have been worked through by Mr. W. B. Wright, who has provided the material for these brief notes on the palaeontological character of the bands.

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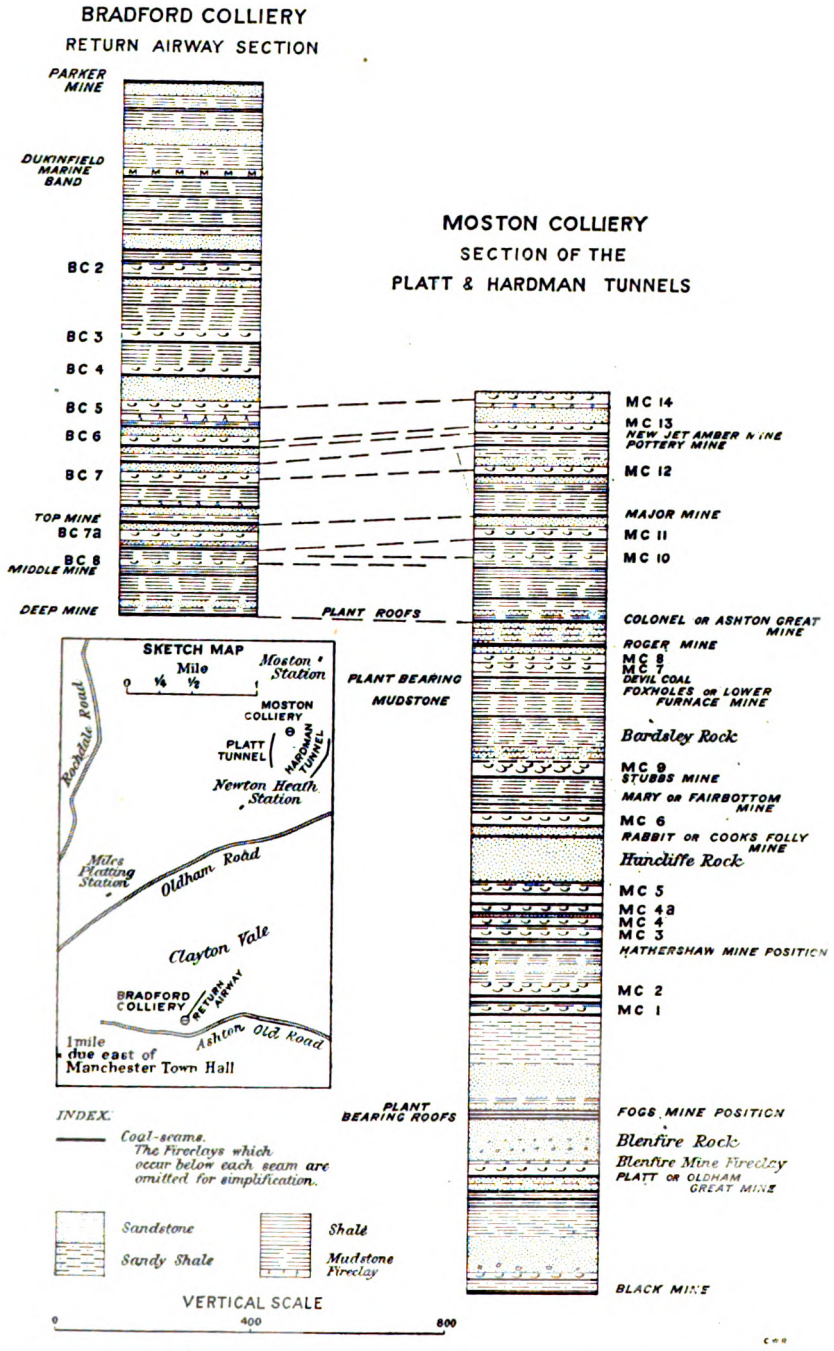

FIG. 1.—*Vertical Sections of the Manchester Coal Measures at Moston and Bradford Collieries.*

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It can be seen in Fig. 1 that there is an overlap between the Bradford and Moston sections of 480 ft. The lithological character of the measures and the distances apart of the coal seams compare sufficiently well to give an approximate correlation of the Bradford Deep Mine with the Moston Colonel, but another check is available in the *Carbonicola* bands which occur in this " overlap."

The bands marked M C 12 and B C 7 both occur over a coal 1 ft. 6 in. thick, and lie at the same vertical distance above the Major Mine in .the one case, and the Bradford Top Mine in the other. Numerous forms occur, including varieties restricted to this horizon, which are common to both localities. This is so marked a feature that there can be no doubt of the identity of these two bands. No differences have been observed in the fauna of M C 13 and B C 6 and there is no reason to doubt that they are the same bed. M C 14 is poorer in fauna than B C 5, but there is no distinctive character in either.

The other bands of the " overlap " are extremely interesting. B C 7a and M C 11 may not be on precisely the same horizon, but there is no evidence to show that this is the case. They are totally distinct in fauna and this difference is accompanied by a change in lithological character. Small species of *Anthracomya* and *Carbonicola* occur in B C 7a in grey mudstone, with a thin calcareous band at the base. M C 11 consists of about 3 inches of *Carbonicola* limestone and 1 ft. of black shale in which species of *Anthracomya* are found. These bands are not only different as between themselves, but they do not resemble other bands above or below. It seems most probable that the difference between the two is due to a lateral change in lithological and palaeontological character between Moston and Bradford.

There are differences in the faunas of the bands B C 8 and M C 10 but the two bands are on different stratigraphical horizons. B C 8 occurs in cannelly shale about 5 ft. above the Bradford Middle Mine. The same shale occurs above the equivalent coal at Moston, but did not yield fossils. The scantiness of the fossils at Bradford had been so marked that little surprise was occasioned by their absence at Moston. M C 10 is a *Carbonicola* limestone 45 ft. above the coal with the cannel shale roof, and at Bradford no fossiliferous band was found in this position. The two bands are linked, however, by the presence in both, of specimens of a small ovoid *Carbonicola* with wrinkled periostracum ; a form which has not been observed at any other horizon.

Of the six *Carbonicola* bands which occur in the 400 ft. of beds above the Colonel Mine, the M C 12—B C 7 band is by far the most important. This statement is not made merely on account of the fact that the faunas at Bradford and Moston are the same, but because elements of its fauna are sufficiently distinct from those of the bands above and below to render the observed faunal identity a thing of real value. This being the case, the correlation of the Bradford Top Mine with the Major Mine of Moston, and the correla-

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tion of the coal next above B C 7 with the Pottery Mine of Moston is confirmed.

The Pottery Mine of Moston and Bower is the Sod Mine of Dukinfield,[1] and 600 ft. above the Sod Mine lies the marine band discovered long ago by Green. The final confirmation of the

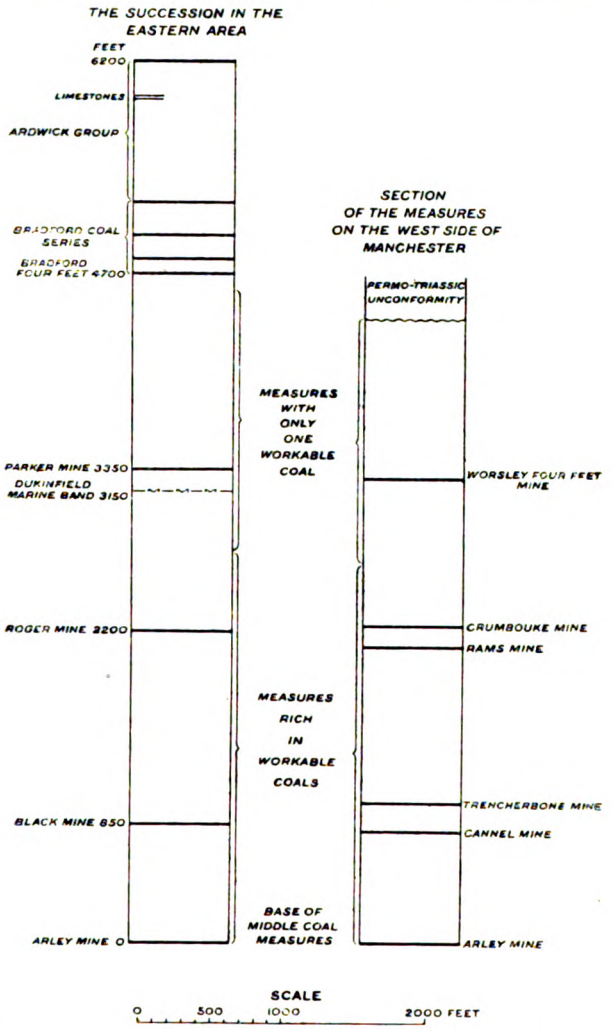

FIG. 2.—*Vertical Sections of Coal Measures east and west of Manchester.*

correlation put forward by Professor Hickling is afforded by the discovery of a marine band 600 ft. above the coal that is correlated with the Pottery Mine in the Bradford section. The band consists of 1 ft. 3 in. of limestone with marine shale above it. The fauna

[1] Lloyd, W., 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 63, fig. 2.

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does not appear to be either rich or well-preserved, and in this respect, as in lithological character, it resembles the band at Dukinfield. Marine fossils have not been found elsewhere in the sections examined.

The fresh limestone of the band is exceedingly hard and over a foot thick, and its character should preclude the possibility of its having been overlooked by shaft sinkers and borers. Yet although these measures were bored through below the Parker shaft, and the Deep shaft passes through them, no record of this limestone occurs in the journals of either boring or shaft sinking. This hard resistant rock is included in the item : " Metal : 8 yds. 2 ft. 2 ins." in the one case, and in : "Grey bind : 65 ft. 10 ins." in the other. In view of the use to which the Abdy and Mansfield Marine Beds have been put in the Yorkshire and Nottinghamshire Coalfields and the lack of any knowledge as to the extensive occurrence of any similar horizons in Lancashire, the omission becomes all the more startling, and, in addition, seems to emphasise the importance of the detailed examination of such tunnel sections as can still be seen.

At the top of the succession in the isolated Manchester (Bradford) Coalfield occur the red beds of the Ardwick Series, the highest Carboniferous strata known in Lancashire, and although the relation of these to the Bradford coals has always been clearly understood, it is only recently, as Professor Hickling points out,[1] that their position with reference to the Oldham succession to the east has been realised. Fig. 2 gives a skeleton section of the complete sequence on the eastern side of the coalfield. For the sake of comparison, and, it may be added, clarity, a section of the measures in the Pendleton area, on the west side of Manchester, is placed alongside. No correlation of any part of these two sections is here attempted or intended, but it is at least clear that the earlier correlation of the Bradford 4-ft. Mine with the Worsley 4-ft. Mine introduced much of the confusion that has arisen.

[1] ' Sections of Strata of the Coal Measures of Lancashire,' 1927, p. 21.

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V.—THE ROCHDALE ROAD SEWER TUNNEL SECTION, MANCHESTER

By Laurance H. Tonks, M.Sc.

Text-figures 1 and 2.

The cutting of a large sewer tunnel along Rochdale Road, Manchester, provided a splendid opportunity for the examination of the Permo-Triassic rocks and Coal Measures west of the St. George's Fault, which had previously been seen only in scattered exposures in the Irk valley.[1] The section described in this paper extends along Rochdale Road from a point 30 yds. south of Nelson Street, Newton, to Pickering Street, Harpurhey. Along this portion solid rock was seen continuously, but from Pickering Street northwards to Blackley the tunnel was cut in drift. This was also the case in the southerly continuation of the sewer from Nelson Street to Miller Street and along Great Ancoats Street, except where Bunter Sandstone was proved in places.

A section of that part of the tunnel which is to be described is given in Fig. 2. It is 10 ft. in diameter at the Nelson Street end and 9 ft. at Pickering Street, and lies at depths varying from 100 to 180 ft. below the surface. Shafts were sunk to tunnel level at Ashton Street, Zinc Street, Collyhurst Street, Paget Street, Scropton Street and Central Avenue.

Description of the Section.—The marly red sandstone (Bunter) seen south of Nelson Street calls for little comment. It did not contain pebbles here or south of Central Avenue. An increase in marliness downwards marked its passage into the Manchester Marls below. These red marls were not fully exposed in the sewer, as a fault at Limer Street cut out part of their thickness. This appears to be about 150 ft. in this district, from evidence afforded by surrounding boreholes. 98 ft. of marl was proved in the sewer, so that the throw of the Limer Street fault is about 50 ft. down to the south. Immediately south of the fault the beds dip at 7° south-west, but to the north their dip is 14° in the same direction.

In this part of the sewer no fossiliferous limestone bands were present in the marls. This affords an illustration of the varying character of these thin limestones, for Binney has described[2] fossiliferous limestone bands from the sections formerly exposed in the valley of the Irk at a point only 300 yards north-west of this sewer tunnel section.

The junction of the marls with the underlying Collyhurst Sandstone was a conformable one ; and this observation confirms that

[1] One-inch Sheet 85 ; six-inch map, Lancs. 104 N.E.

[2] 'Sketch of the Geology of Manchester and its vicinity,' *Trans. Manch. Geol. Soc.*, vol. i, 1841, pp. 54-6.

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made long ago by Binney in the Irk valley.[1] The Collyhurst Sandstone presented its usual characters of a soft red medium grained sandstone, with coarser bands of millet seed grains. Such bands were found throughout the rock. The full thickness proved in the sewer was 293 ft., and the base of the rock was uneven and cut across the bedding planes of the Coal Measure shales below.

A vertical thickness of 915 ft. of Coal Measures was proved from Zinc Street northwards to the big fault 250 yds. south of Boardman Street. The character of these measures is shown in the vertical section (Fig. 1) and their position in the horizontal section (Fig. 2). No fossils were seen anywhere in this belt of strata. The red and variegated marls immediately below the Collyhurst Sandstone belong to the Upper Measures (the Ardwick Limestone Series). Their base is taken at the 4-in. coal seam, below which grey and normal type Coal Measures become dominant. The fault north of the Collyhurst Street shaft throws down northwards, i.e. against the dip; and its effect is, therefore, to repeat beds previously seen in the tunnel. If this fault had any considerable throw, the upper Coal Measure marls and the underlying grey shales with coal seams would have been proved again on the north side of the fault, but as these are absent, it seems certain that the throw can only be a few feet. The fault south of the Scropton Street shaft is considered, for reasons stated later, to have a throw of several hundred feet. The downward change in hade of this fault, from 30° to 45°, is of interest.

The north boundary fault of the Bradford coalfield was proved at a point 250 yds. south of Boardman Street, some distance south of the position provisionally assigned to it by Hull. In the horizontal section (Fig. 2) the hade shown is somewhat greater than the true hade, which is about 45°, as the tunnel cuts the line of the fault obliquely. The approach to this fault was marked by a turnover of the measures, accompanied by repetition and crumpling of the beds against the fault plane. On the downthrow side of this fault the Manchester Marls were proved for a short distance, until faulted against the Bunter Sandstone which extended northwards to the shaft at Central Avenue. About 12 yds. north of the shaft the Manchester Marls were again proved. Drift deposits occupied a small hollow, apparently caused by a fault, at this junction of the marls with the Bunter Sandstone, and the absence of any suggestion of a passage from the marl to the sandstone might be due to such a fault. The marls extended about 250 yds. farther north, but at this point the base of the drift descended below tunnel level.

Correlation.—The only sections with which the measures proved in the sewer tunnel can be compared are those on the east side of the St. George's Fault. The nearest point at which the full thickness of the Collyhurst Sandstone is known is at the Hydraulic Power Station borehole, Pott Street, 1,100 yds. to the south, and on the

[1] *Op. cit.*, p. 57.

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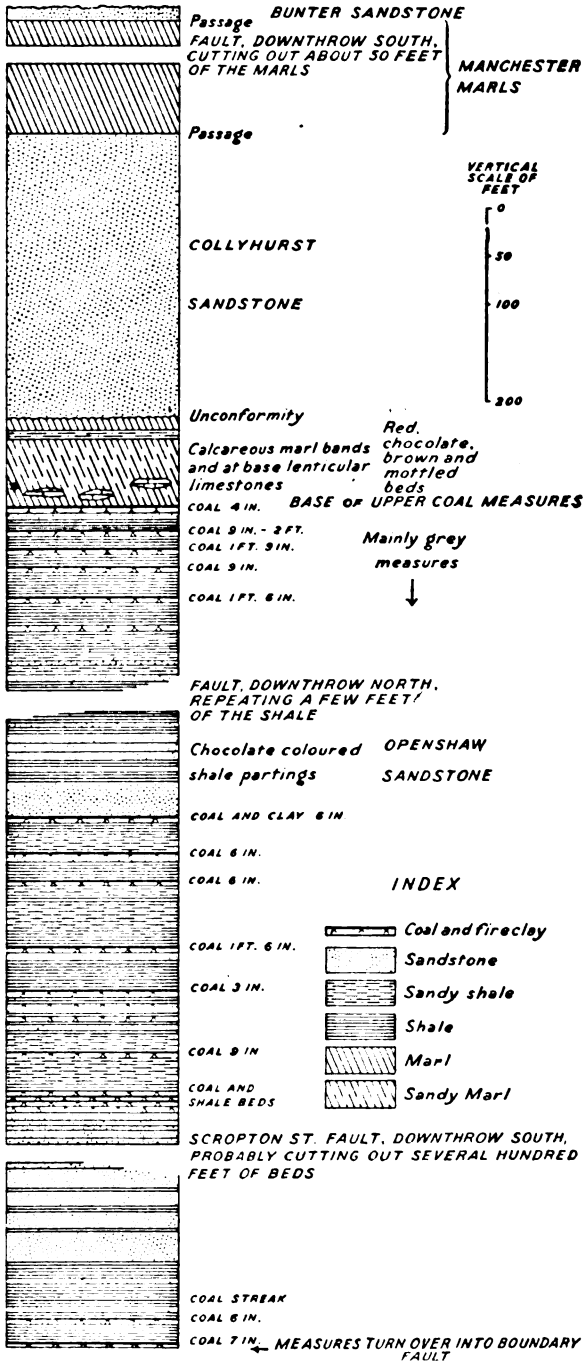

FIG. 1.—*Vertical Section of rocks shown in Rochdale Road Sewer.*

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[1] *Op. cit.*, p. 57.

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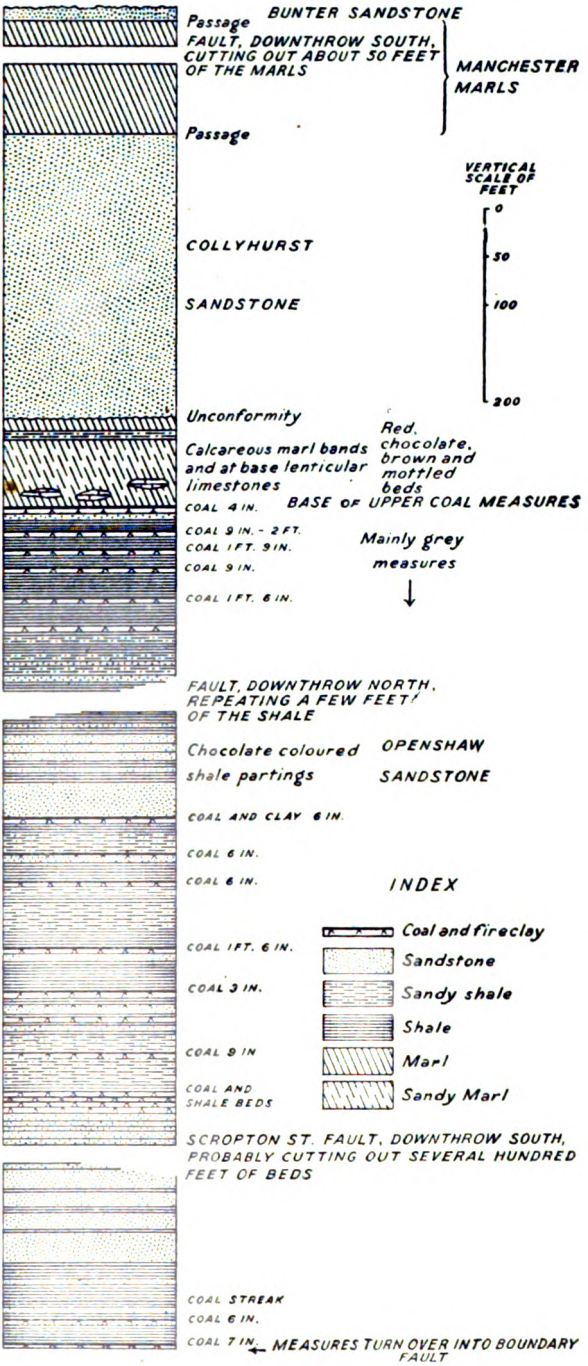

FIG. 1.—*Vertical Section of rocks shown in Rochdale Road Sewer.*

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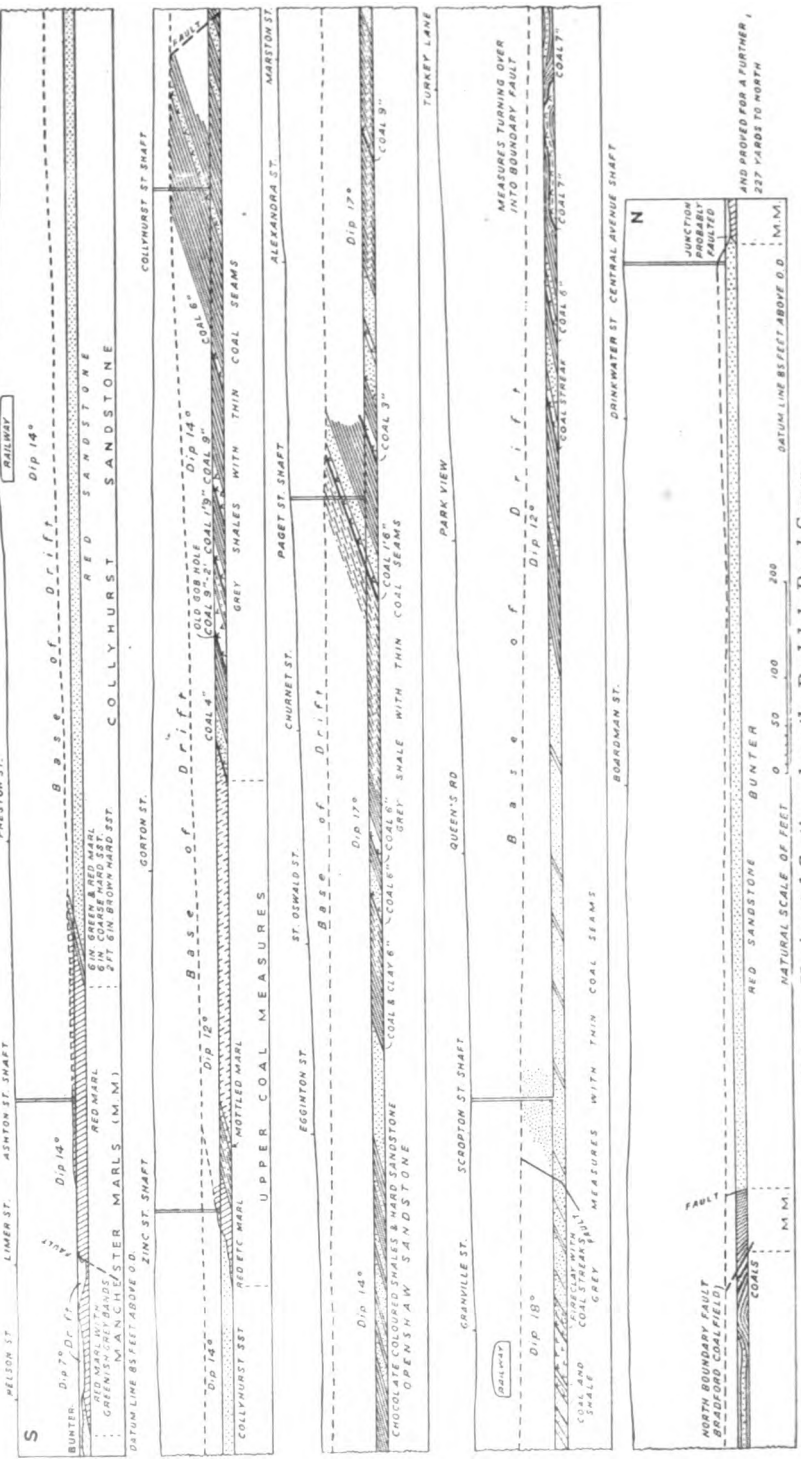

FIG. 2.—*Horizontal Section along the Rochdale Road Sewer.*

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upthrow, or eastern side of the St. George's Fault. The distance separating these points is, of course, less if allowance is made for the post-Triassic movement along this fault. At the tunnel section the Collyhurst Sandstone is 293 ft. thick and at the Pott Street borehole, 136 ft. That this is not simply a normal directional thickening is shown by the fact that 1,100 yds. farther south at Messrs. Deakin's Brewery borehole in Broardie Street, the Collyhurst is 184 ft. thick. It seems impossible to resist the conclusion that there is a causal connexion between the increase in thickness and the positions of the two sections on opposite sides of the St. George's Fault, and that the striking increase in thickness on the downthrow side is due to intra-Collyhurst movement along this fault.

The Pott Street borehole also affords further evidence of the unconformity at the base of the Permo-Triassic rocks. At this borehole the Collyhurst Sandstone is 9 ft. above the Great Mine Limestone, and at the Ardwick Lime Works, one mile away, 300 ft. of marls with limestones occur between this limestone and the base of the Collyhurst.[1] By calculation and projection from the Pott Street borehole it is found that at the sewer tunnel section the base of the Collyhurst is at an horizon about 350 ft. below the Great Mine Limestone. Adding to this the 100 ft. of Coal Measure marls proved in the tunnel, it appears that the base of the red and variegated marls lies at a distance of 450 ft. below the Great Mine Limestone. The characters of the beds below this limestone are not known at Ardwick, but, as Professor Hickling has pointed out[2], these measures have been proved in the High St. Baths borehole, where 600 ft. of red and variegated marls and shales were found to lie below the Great Mine Limestone.

There is very little definite information to work with in making a comparison between the Coal Measures of the tunnel section and the series at Bradford. The uppermost known seam of the Bradford Series is the Openshaw Mine, about 700 ft. below the Great Mine Limestone. This, an estimated vertical distance calculated from the old exposures in the valley of the Medlock,[3] is probably fairly accurate, as the dip and the absence of faulting are proved by the extensive mining operations which have taken place in this area. 400 ft. of measures separate the Openshaw Mine from the Bradford 4-ft. Mine, of which the uppermost 150 ft., above the Charlotte Mine, are unknown. Below the Bradford 4-ft. Mine, 2,430 ft. of Coal Measures have been proved in the Deep Shaft at Bradford Colliery.

Thus, very little is known of the beds between the Great Mine

[1] Dickenson, J., 'The Leading Features of the Lancashire Coalfield,' *Trans. Manch. Geol. Soc.*, vol. 29, 1904-6, p. 244.

[2] Hickling, G., 'The Geology of Manchester as revealed by borings,' *Trans. Inst. Min. Eng.*, vol. liv, 1918, p. 382.

[3] See Binney, E. W., 'Sketch of the Geology of Manchester and its Vicinity,' *Trans. Manch. Geol. Soc.*, vol. i, 1841, pp. 35-66; J. Dickenson, 'On the Coal Strata of Lancashire,' *op. cit.*, vol. 4, 1862-4, pp. 155-175; and the more recent discussion by Hickling in his paper on the Geology of Manchester.

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Limestone and the Charlotte Mine. Dickenson's section [1] at Newton and Ardwick is very generalised, and in the upper part consists of such items as " Coal : 3 ins. ; Shale, etc., with sandstone, called the Openshaw Sandstone : 146 yds." This section serves chiefly to show that two important sandstones, the Holt Town Sandstone, and the Openshaw Sandstone, are found in this belt of strata ; but their precise position is indefinite. Mellor's section of the Ardwick Series,[2] however, gives the position of the Holt Town Sandstone at about 70-80 ft. below the Great Mine Limestone. This limestone and the Holt Town Sandstone, however, disappear westwards below the Permo-Triassic unconformity before the St. George's Fault is reached. Consequently in the sewer tunnel section it is probable that the thick sandstone series occurring about Egginton Street represents the Openshaw Sandstone. From the old map it appears that the Openshaw Mine, 3 ft. thick, lies immediately below this sandstone at Bradford. The absence of any coal of this thickness in the tunnel may perhaps be explained by supposing that it has been cut out by the overlying sandstone. In any case, there does not appear to be any other known rock near the probable stratigraphical horizon of these measures to which this sandstone of the tunnel section can be assigned. Assuming the approximate correctness of this correlation, then a comparison with Dickenson's section and the sections of the Bradford Colliery shafts suggests that the 1 ft. 6 in. coal below may be the Charlotte Mine (Fig. 1), and that the coal and shale beds immediately above the lowest fault may be about the horizon of the Three Quarters Mine. This suggested correlation involves the assumption that the Bradford 4-ft. Mine is cut out by the Scropton Street fault. The roof of this coal is so well characterised [3] that its presence in the tunnel section could not have been overlooked. It must be borne in mind that no great certainty is felt in the correlation set out above, and that it is to be considered simply as a working hypothesis, held for the present until further boring or other explorations lead to a more precise correlation.

In the measures on the north (upthrow) side of the Scropton Street fault a thick and massive sandstone is the only striking feature. As this fault throws down to the south-west, that is, in the same direction as the dip, these beds are older than those to the south. If the throw of this fault is comparatively small this sandstone lies about the horizon of the Bradford 4-ft. Mine or a little below it. The first thick sandstone below the Openshaw Sandstone, however, is a rock 120 ft. in thickness, 820 ft. below the 4-ft. Mine ; and it would seem that this is the only sandstone in the sequence proved at Bradford with which the Scropton Street sandstone can be compared. If this is the correct reading of this part

[1] *Trans. Manch. Geol. Soc.*, vol. 4, 1862-4. Chart.

[2] Dickenson, J., 'The Leading Features of the Lancashire Coalfield,' *Trans. Manch. Geol. Soc.*, vol. 29, 1904-6, p. 244.

[3] Gerrard, J., 'Notes on fossils found above the Bradford Four Feet Coal at Bradford Colliery, Manchester,' *Trans. Manch. Geol. Soc.*, vol. 28, 1902-4, pp. 555-562.

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of the section, then the Scropton Street fault is a branch of the St. George's Fault, taking on the greater part of the throw of the latter.

The correlation of part of the measures proved in the tunnel with the measures above the Bradford 4-ft. Mine involves certain difficulties. By calculation it was found that the base of the red upper Coal Measures in the sewer tunnel section lies at a distance of 450 ft. below the Great Mine Limestone. Adding to this the 640 ft. of ' normal ' Coal Measures, which by the suggested correlation are considered to be above the Bradford 4-ft. Mine, the figure of 1,090 ft. is arrived at for the distance between the Great Mine Limestone and the Bradford 4-ft. This agrees well with the thickness between these beds at Newton and Aɾdwick, which is 1,100 ft. The High Street Baths borehole, however, shows a thickness of 600 ft. of red and variegated measures below the Great Mine Limestone. Although situated $2\frac{1}{2}$ miles south of the sewer section, this evidence cannot be ignored, as it is the only place in which any thickness of measures below the Great Mine Limestone has been proved. If it be assumed that the calculated thickness of the red measures at the sewer tunnel is correct, and that there is approximately the same distance between the Great Mine Limestone and the Bradford 4-ft. in the different localities, then the difference in thickness of the red measures may be explained by postulating lateral change in the character of the strata. That is, that beds which are normal Coal Measures at the sewer section change into red measures southwards. On the other hand, some unforeseen error of calculation or projection may nullify the estimated thickness of red beds at the sewer tunnel ; and if this thickness is here also about 600 ft., not 450 ft., then there is, on the downthrow side of the St. George's Fault, about 1,250 ft. of beds between the Great Mine Limestone and the Bradford 4-ft. Mine, compared with 1,100 ft. on the upthrow side of the fault. Such a state of affairs would be explained by postulating movement along this fault during the deposition of the upper part of the Coal Measures. The downthrow of the fault in the Coal Measures is about 900 ft. and this is much greater than the total of the movements which took place :

(*a*) possibly during the deposition of the upper part of the Coal Measures ;
(*b*) during the deposition of the Collyhurst Sandstone ;
(*c*) after the deposition of the Bunter ;

so that there must also have been another movement, probably the main one, along this fault line after the deposition of the Coal Measures, and before the Collyhurst Sandstone was laid down.

Mining operations in the Parker Mine, 1,350 ft. below the Bradford 4-ft., have been carried some distance beyond the position in which this fault should have been proved in the deeper seam if its apparent hade in the upper measures continued downwards. At depth, therefore, its hade must increase fairly rapidly, and in this connexion it is perhaps of interest to note the flattening of the plane of the Scropton Street fault, which, for other reasons, has been

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taken to be a branch, taking most of the throw of the St. George's Fault.

In conclusion, the writer wishes to express his thanks to the Manchester City Engineer, Mr. J. B. L. Meek, for permission to examine the section; and also his indebtedness to the Resident and Assistant Engineers, Messrs. Bullough, Kent, Uttley and Ashworth, for the ready way in which they facilitated the work of visiting the tunnel.

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VI.—WHITTINGTON RAILWAY CUTTING

By G. V. Wilson, B.Sc.,

Text-figure 1.

An excellent section of the measures between the Yard and the Deep Hard Coals has recently been exposed in the process of widening the cutting on the London Midland and Scottish Railway (main line) between New Whittington and Barrow Hill stations, about three miles north east of Chesterfield. In the course of the investigation we have been greatly helped by Mr. R. T. McCallum of the railway engineering staff. He has presented us with a section from which the diagram (Fig. 1) is reduced, and the lists of fossils are mainly compiled from specimens collected by Mr. W. C. Whitmore of the L.M.S. The section was also visited by Mr. S. G. Clift of University College, Nottingham, who has furnished us with information about certain of the beds of fresh water mollusca. The plants have been named by Dr. R. Crookall of the Geological Survey, and the mollusca by Dr. A. E. Trueman of University College, Swansea.

The cutting is situated on the eastern side of the Brimington anticline about 300 yds. north east of New Whittington Station in One-inch Sheet (N.S.) 100; Six-inch Sheet, Derby 18 S.W. The beds dip E.N.E. at an angle of about 24 degrees, and the strike crosses the rails at an angle of about 75 degrees.

The section starts about 150 ft. above the Silkstone Coal which outcrops 100 yds. east of Whittington Station. The lowest beds consist of shaly sandstones and are considered to represent the Silkstone Rock. Six well developed coal seams were exposed. Their names are given below, and compared with those given on a tracing taken from a section prepared in 1844, soon after the railway was made.

New Cutting	Old Cutting
Deep Hard	Potters
Piper	Piper
Hospital or 2nd Piper	(Not named)
Tupton or Low Main	(Not named)
Tupton Three Quarter	Tupton or Dogtooth
Yard	Tupton Three Quarter

At Fouleyoaks Colliery near Old Whittington the Hospital is described as the Dogtooth, The Tupton as the Cockle Shell and the Tupton Three Quarter as the Tupton. From the above it will be seen that much confusion exists in the naming of the seams in this part of the country. The work of Dr. Trueman and Mr. Clift on the fresh water mollusca of the Middle Coal Measures of Nottinghamshire is beginning to throw light on the correlation of the various seams. For instance it has been found that the shales above the

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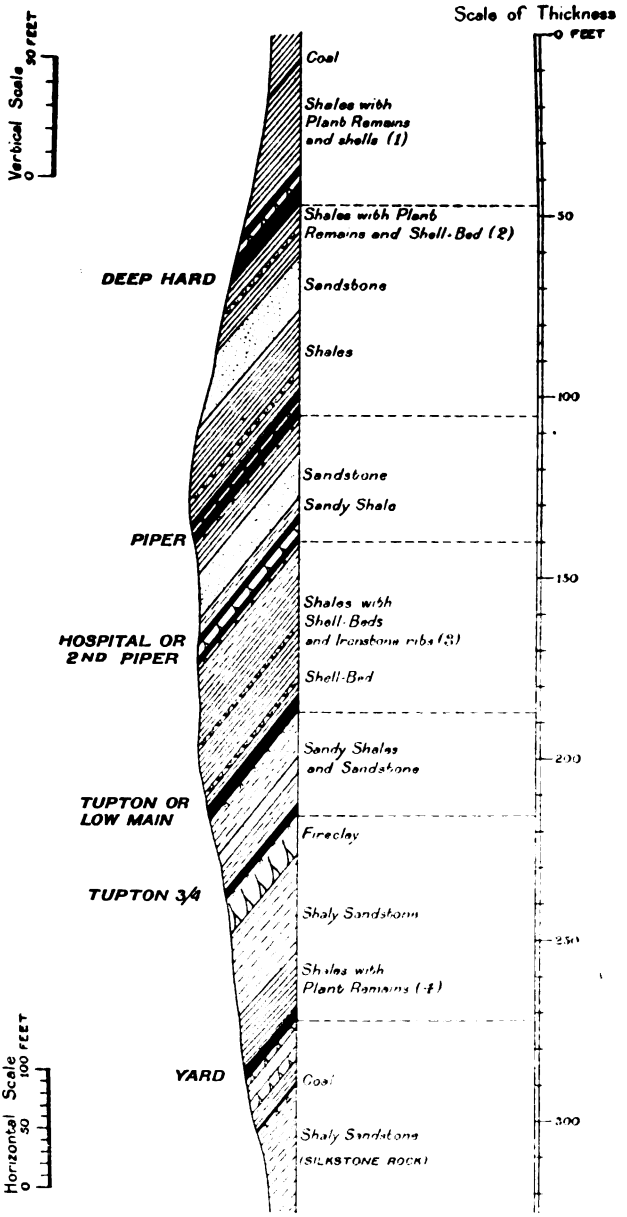

FIG. 1.—*Horizontal Section of the Whittington Railway Cutting.*

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Tupton or Low Main seam are characterised by the presence of certain facies of the shells *Carbonicola rhomboidalis* and *C. acuta*. These forms are well developed in the shell-beds which occur in the shales that are shown in the section (Fig. 1), as occurring between the Tupton and 2nd Piper Coals.

LIST OF FOSSILS.

Animals.

Fresh water mollusca.

Carbonicola *cf.* acuta (*J. Sow.*) (1) (3).
" *cf.* communis *Davies and Trueman* (3).
" *cf.* ovalis (*Martin*) (3).
" *cf.* robusta (*J. de C. Sow.*) (3).
" *cf.* rhomboidalis *Hind* (2) (3).
Naiadites *cf.* triangularis (*J. de C. Sow.*) (3).

Plants.

Cordaitales.

Cordaites principalis (*Germar*) (1) (4).

Equisetales.

Asterophyllites charaeformis (*Sternb.*) (4).
Calamites carinatus *Sternb.* (4).
" cisti *Brongt.* (4).
" undulatus *Sternb.* (4).
" sp. (4).
Pinnularia capillacea (*L. & H.*) (1).

Filicales.

Asterotheca miltoni (*Artis*) (1).
Dactylotheca plumosa (*Artis*) (1).
Dolerophyllum sp. (2).
Neuropteris heterophylla *Brongt.* (1).
" tenuifolia *Schloth.* (1).
Sphenopteris sp. (1).

Lycopodiales.

Lepidodendron ophiurus *Brongt.* (2) (4)
" sp. (2).
Sigillariophyllum bicarinatum (*L. & H.*) (4).
Stigmaria ficoides (*Sternb.*) (4).

Sphenophyllales.

Sphenophyllum sp. (1) (2).

The figures refer to beds shown on the section (Fig. 1).

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VII.—THE DISTRIBUTION OF SANDSTONES IN THE MEASURES ABOVE THE BARNSLEY OR TOP HARD COAL IN THE NORTHERN PART OF THE CONCEALED COALFIELD OF YORKSHIRE AND NOTTINGHAMSHIRE

By G. V. Wilson, B.Sc.

Text-figures 1 and 2.

The chief difficulty encountered in the process of shaft-sinking in the concealed part of the Yorkshire and Nottinghamshire coalfield is the large volume of water yielded by the soft sandstones of the Trias. The sandstones of the Coal Measures usually are dry, but occasionally this is not the case. In certain instances as much as 1,200 gallons of water per minute have been encountered, and sinking operations have been held up until suitable pumps could be installed.

Although it is not possible to determine whether a sandstone at any locality is likely to yield a lot of water, it is considered that it would be of use, if the number of sandstones that might be met with in a sinking could be ascertained beforehand. With this purpose in view, a number of small maps have been prepared, on which an attempt is made to show the possible lateral distribution of certain sandstone horizons of the Middle Coal Measures.

In an area such as the one under consideration, in which there are no surface exposures of Coal Measures, and where our knowledge of the geological succession is limited to that supplied by shaft-sinkings and borings, it is very possible that the correlation of the various sandstones from section to section is incorrect. It has, however, been found convenient to divide the sandstone horizons into three groups :—

(1) Sandstones above the top Marine Bed (where identified), otherwise above the Shafton Coal.
(2) Sandstones lying between the Top Marine Bed or the Shafton Coal and the Mansfield Marine Bed.
(3) Sandstones between the Mansfield Marine Bed and the Barnsley Coal.

In the preparation of the maps use has been made of the information supplied by the numerous colliery sinkings to the west. A certain amount of generalization of the beds has been necessary ; sporadic thin sandstones have been ignored, and no attempt has been made to follow the outcrops in the exposed ground.

SANDSTONES ABOVE THE TOP MARINE BED

Three main sandstone horizons can be made out in the 1,000 ft.-1,500 ft. of Middle Coal Measures that lie above the Top Marine Bed. It is interesting to note that some of these sandstones have been found to possess a reddish or purple colour when they have been met with in some of the borings in Nottinghamshire.

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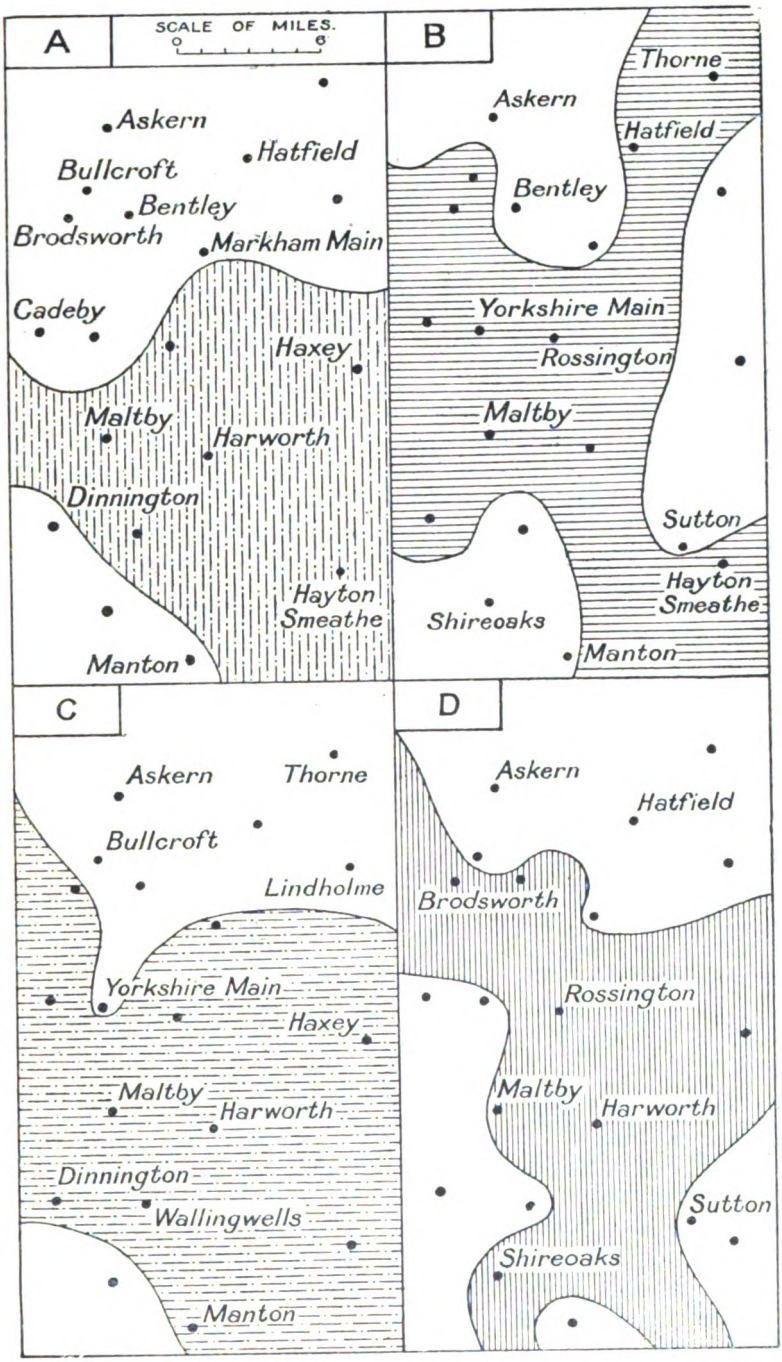

FIG. 1.—*Sketch-map showing Distribution of Sandstones in northern part of the Concealed Coalfield of Yorkshire and Nottinghamshire.*

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The uppermost of the sandstones occurs some 700 ft.—1,000 ft. above the Top Marine Bed. In the area covered by the maps this rock has only been noted at Maltby and Wallingwells. In the north-west, however, a sandstone was encountered in the sinking at Upton, and the well-known Pontefract or Wickersley Rock must occur somewhere about this position.

Sandstone A (Fig. 1).—This horizon is well developed in the area between Maltby, Haxey and Hayton Smeathe where it averages 120 ft. in thickness. It is present at Thurcroft in the west, but is missing at Dinnington. The highest Coal Measures encountered at Shireoaks and Manton lie below this horizon. In the exposed coalfield a sandstone at about this position is known as the Ackworth or Brierley Rock.

Sandstone B (Fig. 1).—In the northern part of the area, from Thorne round by Yorkshire Main to Bullcroft, the thickness of this horizon is about 100 ft. It expands to 200 ft. at Maltby but thins off towards Harworth. No well developed bed of sandstone occurs at this position at Sutton, but 150 ft. was recorded at Hayton Smeathe. Further south the highest Coal Measures present in the boring at Boughton are above this horizon. It is difficult to correlate this sandstone with any definite bed in the exposed coalfield, but beds near this position are known as the Great Houghton Rock and the Havercroft Rock.

SANDSTONES BETWEEN THE TOP MARINE BED AND THE MANSFIELD MARINE BED

Three sandstone positions can be recognised in the 450 ft.—550 ft. of strata that intervene between the Mansfield and the Top Marine Beds. In some instances the thickness of the sediments of sandy type attains to about 200 ft.

Sandstone C (Fig. 1).—This horizon is thickest near Dinnington where it averages about 200 ft. It is absent at Yorkshire Main, but varies from 80 ft.—100 ft. in thickness over most of the area shown on the map. Further south at Boughton near Ollerton the thickness has diminished to about 50 ft. The sandstone known as the Upper Chevet Rock occurs at about the same position in the sequence.

Sandstone D (Fig. 1).—A sandstone at this horizon is well developed at Hemsworth and Nostell to the west of the area. Over most of the district it is only about 50 ft. in thickness, and it is not readily recognised in the ground to the south. Near Cudworth a sandstone at this position is known as the Middle Chevet Rock.

Sandstone E (Fig. 2).—This horizon averages from 50 ft.—70 ft. in thickness over most of the area, but expands to over 150 ft. at Thorne, Hatfield and Yorkshire Main. It is the first thick sandstone above the Mansfield Marine Bed, and in many bore journals and shaft-sections has been recorded as the Oaks Rock. It appears however, that this identification is not correct; since at Cudworth

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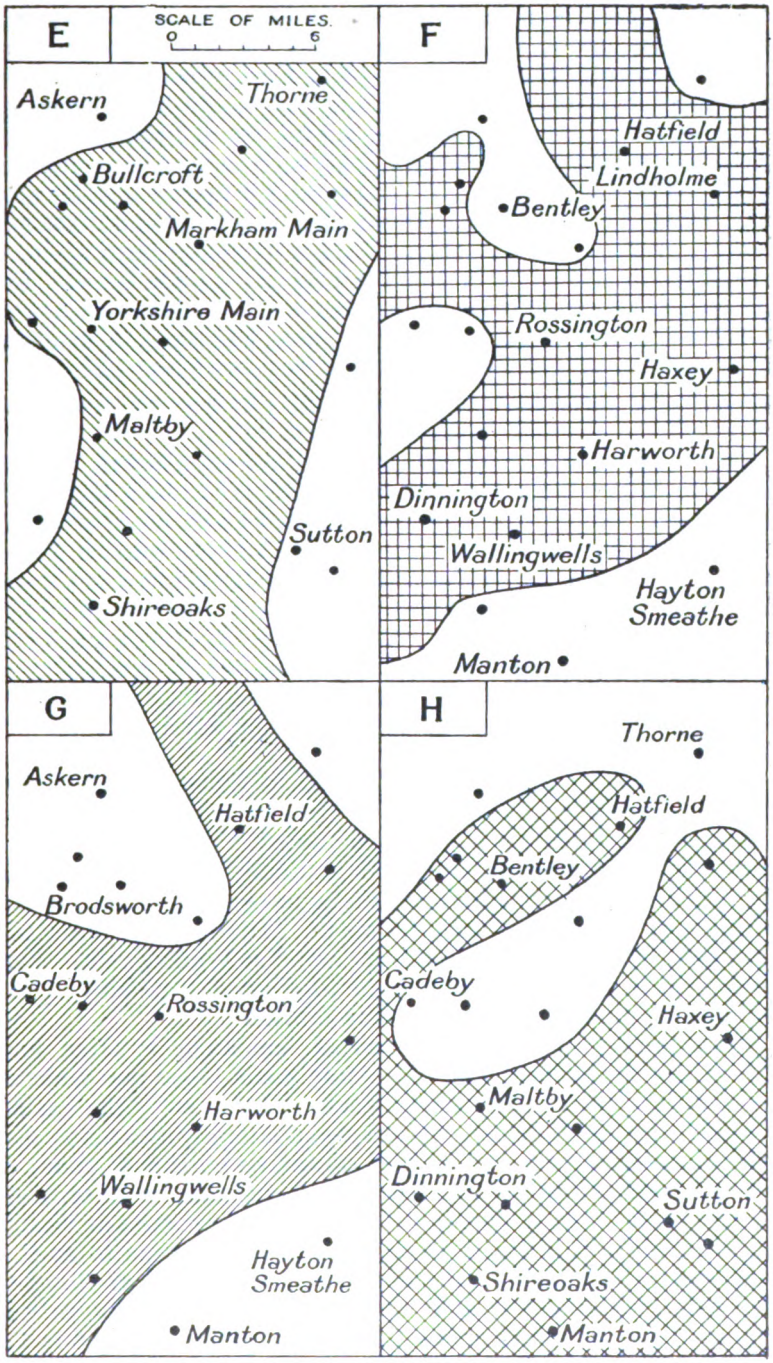

FIG. 2.—*Sketch-map showing Distribution of Sandstones in northern part of the Concealed Coalfield of Yorkshire and Nottinghamshire.*

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and near Wakefield[1], a bed which is considered to be the Mansfield Marine Bed is found to occur above the Oaks Rock of the Oaks district. Recently the base of the Oaks Rock was exceedingly well exposed in the cutting on the L.M.S. Railway, which has been made to replace the Chevet Tunnel. A careful examination of the roof of the underlying Swinton Pottery Coal failed to reveal any trace of a marine bed at this position. At Cudworth the marine bed lies about 200 ft. above the Oaks Rock. It can also be seen in about the same position on the east side of the L.M.S. Railway cutting to the south of Normanton. It is possible that the Lower Chevet Rock may be the representative of Sandstone E. South of Harworth this horizon is only about 50 ft. in thickness, but 100 ft. of sandstone and associated sandy sediments occur in this position at Thoresby.

SANDSTONES BETWEEN THE MANSFIELD MARINE BED AND THE BARNSLEY COAL

In the exposed part of the coalfield near Cudworth two well defined sandstone horizons occur between the Mansfield Marine Bed and the Meltonfield Coal. They are known as the Oaks Rock and the Woolley Edge Rock, and are separated by the Swinton Pottery Coal. As they are traced eastwards and southwards into the concealed area their individuality is lost, and in the Memoir on the Concealed Coalfield the name Woolley Edge Rock is used for the sandstone in this position. In some instances two sandstones can be recognised; as for instance at Maltby, where they are separated by a marine bed. At Dinnington, on the other hand, only one thick sandstone occurs.

Sandstone F (Fig. 2).—This horizon is taken as including the Oaks and Woolley Edge positions. In the Hatfield section two sandstones separated by a coal were noted. When traced south-westwards the intervening measures gradually become more sandy until practically only one horizon can be recognised, about 150 ft. in thickness, at Rossington and Harworth. The same is the case at Dinnington, but two sandstones were noted at Wallingwells. Sandstones occur in this zone at Kiveton Park, but they are either poorly developed or absent in South Nottinghamshire.

Sandstone G (Fig. 2).—A bed of sandstone is often found between the Meltonfield and the Abdy coals. In the Wakefield district it is known as the Abdy Rock. In most of the coalfield the bed is very variable, and it often passes laterally into sandy shale. In the concealed area a well marked sandstone horizon at about this position occurs at Hatfield and Rossington, and thin bands separated by sandy shale occur at Yorkshire Main. Further south at Wallingwells the thickness is about 80 ft. but it has decreased to 20 ft. at Dinnington. The Abdy Coal has not been recognised at Haughton and Sutton, and there is little sandstone in this position in these borings. In many parts of the Concealed Coalfield the Abdy Coal

[1] 'The Concealed Coalfield of Yorkshire and Nottinghamshire' (*Mem. Geol. Surv.*), 1926, p. 33, also 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, p. 62 and 'Summary of Progress' for 1927 (*Mem. Geol. Surv.*), 1928, Pt. I, p. 46.

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has been recognised by the presence of marine fossils in the roof shales, and in other localities the name has been given to a coal with cannel in the roof. The examination of a large number of graphically drawn-up sections of bores and shafts shows, that either there is a great variation in the character of these measures between neighbouring localities, or that the name has not always been applied to the same seam. For instance a well defined thick sandstone horizon occurs in what is considered the same part of the sequence at Cadeby, Yorkshire Main and Rossington. The collieries are in a line and the distance from Cadeby to Rossington is about 6 miles. At the latter locality the Abdy with its marine roof occurs below this sandstone, but at Cadeby the name is given to a seam above it.

Sandstone H (Fig. 2).—This horizon is taken as including the sandstones between the Abdy and the Kents Thick or High Hazel coals. (At Cadeby the coal at 1896 ft. is taken as representing the Abdy of Rossington, and not the one named the Abdy at 1,736 ft.). The horizon is well developed at Bentley, where it is about 120 ft. thick, but over most of the area it averages 30 ft. At Haxey and Sutton a great deal of sandy sediment comes in at this part of the sequence, but there is none recorded at Crosby. Further south usually there is little sandstone in this position.

SANDSTONES BELOW THE KENTS THICK OR HIGH HAZELS COAL

Two thin sandstone horizons, averaging about 20 ft. in thickness often occur in this part of the sequence. The upper one generally is to be found a short distance below the Kents Thick Coal, and the lower one occurs not far above the Barnsley or Top Hard Coal. It is sometimes known as the Barnsley Rock. In Kirkby Lowmoor Shaft a sandstone about 70 ft. in thickness occurs in this position.

An examination of the maps brings out certain points of interest. It will be noticed for instance that most of the beds are well developed in the central area around Maltby and Harworth, and that all of them are absent at Askern.

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VIII.—UPTON COLLIERY SINKING

By G. V. Wilson, B.Sc. and D. A. Wray, Ph.D., M.Sc.

Text-figure 1.

The examination of the materials of this sinking has thrown a great deal of light on the geological sequence and structure in this part of Yorkshire. Through the courtesy of Mr. R. Graham we were permitted to watch the operations from their commencement. We also received much valuable help from Messrs. W. Dallas and A. G. Lole.

The colliery is situated at Upton, on the western edge of the outcrop of the Magnesian Limestone, and about half-way between Doncaster and Pontefract. An examination of the ground shows the presence of a fault which throws down the base of the Magnesian Limestone from the outcrop on Upton Beacon, to near the site of the shafts. The difference in level is about 50 ft. In the sinking of the East or No. 1 shaft a zone of highly inclined measures was encountered between the depths of 140 ft. and 375 ft., and disturbed strata occurred from 60 ft. to 420 ft. Above and below these depths the dip of the measures was similar to that in the West or No. 2 Shaft. The strike of the upturned beds is north-east and the dip averages about 70 degrees. This implies that the true thickness of the 235 ft. of highly inclined beds is only about 85 ft. The two shafts are 60 yds. apart, and the line of movement passes between them. It was not possible to correlate with accuracy any of the beds in or above the disturbed zone with those in the West Shaft. Below that position, however, the sequence is practically the same in both shafts. A coal 13 in. thick in the East Shaft at 516 ft. is considered to be the same as one 14 in. thick at 507 ft. in the West Shaft. The Shafton Coal, 3 ft. thick, occurs at 896 ft. in the East Shaft and 883 ft. in the other, and the Mansfield Marine Bed is at about 1,380 ft. in both shafts.

There is no doubt that a great displacement of the measures takes place along this line of movement, but it is difficult to say what the amount is. A minimum figure can be arrived at by adding the 50 ft. which the base of the Magnesian Limestone is known to be displaced, to the 150 ft. which represents the difference between the true and the apparent thickness of the measures in the highly disturbed zone. This gives a figure of 200 ft. The diagram (Fig. 1) shows a possible representation of the geological structure of this line of movement.

In the sinking of the West Shaft a thick mass of sandstone was encountered at the surface. This yielded as much as 1,200 galls. of water per minute and greatly impeded the operations.

In the West Shaft the Top Marine Bed was well marked at 852 ft.

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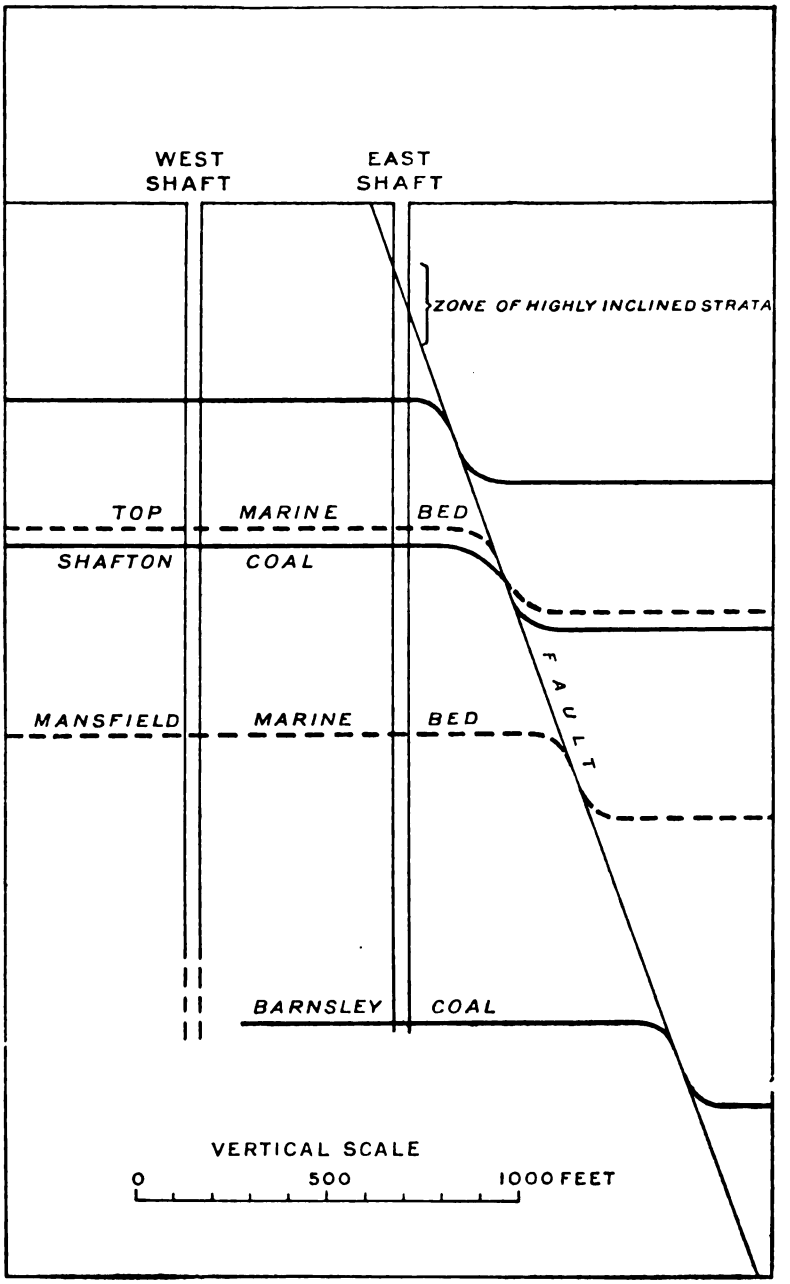

FIG. 1.—*Diagram to show the possible relations of the fault at Upton Colliery.*

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It yielded *Pterinopecten, Ctenodonta, Lingula,* a nautiloid and numerous fucoid markings. The Mansfield Marine Bed occurred 528 ft. lower at 1,380 ft. There was no cank, and the fossils, which were scarce, were similar to those from the Top Marine Bed with the exception that fragments of goniatites occurred, and no nautiloid was noticed.

The distance between the Mansfield Marine Bed and the Barnsley Coal is 751 ft., or 25 ft. less than would have been expected from an examination of the map shown in the *Summary of Progress* for 1925.[1]

The upper part of the detailed section given below is taken from the West Shaft down to the position of the coal at 507 ft., which is taken as being the same as that at 516 ft. in the East Shaft.

Upton Section

One-inch Sheet (N.S.) 78 ; Six-inch Map, Yorks. 264 N.W.
Communicated by Mr. R. Graham.
Heights above O.D., West Shaft 199.2 ft. ; East Shaft 209 ft.
(Slightly abridged).

	Thickness. Ft.	In.	Depth. Ft.	In.
Top portion (West Shaft).				
Clay	—	—	—	—
Sandstone	—	—	65	3
Coal and dirt	5	10	71	1
Fireclay	4	2	75	3
Sandstone	17	10	93	1
Coal	—	2	93	3
Fireclay	2	9	96	0
Bind with ironstone nodules	26	10	122	10
Sandstone	1	9	124	7
Fireclay	1	8	126	3
Coal	—	9	127	0
Bind and fireclay	27	5	154	5
Sandstone	6	3	160	8
Bind and shale	21	2	181	10
Sandstone and sandy bind	14	9	196	7
Black shale and fireclay	1	7	198	2
Coal	—	2	198	4
Blue and black shale	50	2	248	6
Sandstone	9	10	258	4
Stone bind	21	7	279	11
Black shale, coal and fireclay	1	9	281	8
Sandstone and sandy shale	14	10	296	6
Shale and fireclay	35	3	331	9
Stone bind	13	10	345	7
Coal and bat	1	10	347	5
Clunch	4	1	351	6
Stone bind and clunch	11	1	362	7
Coal	—	3	362	10
Stone bind	10	11	373	9
Coal and black shale	—	7	374	4
Bind and clunch...	6	8	381	0
Coal	1	0	382	0
Clunch and stone bind	10	3	392	3
Clunch and black shale	3	9	396	0

[1] 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, p. 61.

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	Thickness. Ft.	In.	Depth. Ft.	In.
Coal	—	8	396	8
Grey and dark bind and clunch	59	6	456	2
Sandstone and stone bind	18	11	475	1
Coal and fireclay	—	5	475	6
Sandstone and stone bind	30	5	505	11
Coal (At 516 ft. 8 in. *in the East Shaft*) ...	1	2	507	1
Bottom portion (East Shaft).				
Coal	1	1	516	8
Fireclay, bind and stone bind	32	2	548	10
Sandstone	12	2	561	0
Stone bind	8	11	569	11
Coal	1	4	571	3
Fireclay, clunch and stone bind	19	4	590	7
Coal	—	7	591	2
Stone bind	11	4	602	6
Coal and clunch	1	5	603	11
Clunch and stone bind	7	4	611	3
Sandstone and stone bind	89	9	701	0
Blue and grey bind	10	4	711	4
Stone bind with sandstone ribs	37	5	748	9
Blue bind	10	9	759	6
Stone bind and clunch	28	10	788	4
Coal and dirt	—	9	789	1
Clunch and stone bind	13	10	802	11
Coal	—	6	803	5
Blue bind (TOP MARINE BED at the base)	48	11	852	4
Stone bind	28	6	880	10
Sandstone	10	10	891	8
Black bind	1	5	893	1
Coal (SHAFTON)	3	3	896	4
Clunch	1	4	897	8
Coal and fireclay	1	5	899	1
Stone bind and sandstone bands	8	8	907	9
Blue and black bind	10	2	917	11
Coal	—	2	918	1
Sandstone	85	3	1,003	4
Coal	—	9	1,004	1
Stone bind and sandstone	64	7	1,068	8
Black bind	11	7	1,080	3
Coal	2	9	1,083	0
Strong clunch	10	9	1,093	9
Blue bind and stone bind	25	4	1,119	1
Sandstone	45	8	1,164	9
Coal dirt and clunch	5	4	1,170	1
Sandstone	63	1	1,233	2
Blue bind	12	3	1,245	5
Coal 1ft. 5 in., dirt 3 in., coal 1 ft.	2	8	1,248	1
Clunch and bind...	24	7	1,272	8
Stone bind with sandstone ribs	88	3	1,360	11
Blue bind with ironstones nodules (MANSFIELD MARINE BED)	19	1	1,380	0
Dark bind	1	11	1,381	11
Coal 2 in., clunch	4	1	1,386	0
Bind and stone bind	33	8	1,419	8
Coal	—	1	1,419	9
Clunch	5	8	1,425	5
Stone bind and blue bind	74	6	1,499	11

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	Thickness. Ft.	In.	Depth. Ft.	In.
Blue and black bind	11	0	1,510	11
Clunch, stone bind and sandstone	12	8	1,523	7
Blue bind	11	7	1,535	2
Coal	**1**	**9**	**1,536**	**11**
Clunch	6	1	1,543	0
Blue bind...	8	11	1,551	11
Sandstone and stone bind	25	5	1,577	4
Blue bind	19	0	1,596	4
Stone clunch	5	8	1,601	0
Blue and black bind	8	0	1,609	0
Coal	—	**9**	**1,609**	**9**
Clunch	3	0	1,612	9
Stone bind	22	3	1,635	0
Blue bind	15	6	1,650	6
Stone bind	25	5	1,675	11
Blue and black bind	13	9	1,689	8
Coal 1 ft. 7 in., dirt 7 in., Coal 1 ft. 10 in. ...	**4**	**0**	**1,693**	**8**
Clunch and bind...	20	4	1,714	0
Coal	**1**	**6**	**1,715**	**6**
Clunch	1	10	1,717	4
Sandstone and stone bind	21	0	1,738	4
Coal	**1**	**4**	**1,739**	**8**
Clunch, stone bind and sandstone	15	6	1,755	2
Bind	11	3	1,766	5
Coal	**2**	**5**	**1,768**	**10**
Clunch	6	3	1,775	1
Sandstone	12	1	1,787	2
Mussel Bed	—	3	1,787	5
Coal (Cannel)	—	**4**	**1,787**	**9**
Stone bind	22	3	1,810	0
Black bind	8	8	1,818	8
Coal 3 in., clunch	5	0	1,823	8
Stone bind and dark bind	20	10	1,844	6
Coal, good	**2**	**8**	**1,847**	**2**
Clunch and stone bind	19	5	1,866	7
Bind	16	8	1,883	3
Coal	—	**4**	**1,883**	**7**
Clunch	7	7	1,891	2
Stone bind	2	0	1,893	2
Coal 1½ in., clunch.	8	0	1,901	2
Bind and stone bind	26	7	1,927	9
Coal	**1**	**2**	**1,928**	**11**
Clunch	4	10	1,933	9
Stone bind	8	4	1,942	1
Blue bind	17	3	1,959	4
Mussel Bed	—	1	1,959	5
Coal (Cannel)	**2**	**0**	**1,961**	**5**
Clunch and bind...	13	2	1,974	7
Coal	—	**8**	**1,975**	**3**
Clunch	2	7	1,977	10
Blue bind	23	7	2,001	5
Stone bind	14	8	2,016	1
Coal and bind	—	3	2,016	4
Clunch and stone bind	18	4	2,034	0
Blue bind	28	2	2,062	2
Clunch	5	4	2,067	6

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	Thickness. Ft.	In.	Depth. Ft.	In.
Coal 1 in., black bind	—	8	2,068	**2**
Stone bind	50	1	2,118	3
Coal ...	**2**	**0**		
Clunch ...	2	0		
Coal ...	—	**5**		
Shale ... BARNSLEY COAL ...	—	10		
Coal (Top)	**3**	**9**		
Dirt	—	10		
Coal (Bottom)	**4**	**11**	**2,133**	**0**
Clunch				

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IX.—ON THE GLACIATION OF THE NORTH COTTESWOLD AREA.

By H. G. Dines, A.R.S.M.

Text-figure 1.

The mode of occurrence of the drift in the North Cotteswolds has long been a subject of controversy, and in the absence of a systematic survey, theories put forward have been largely a matter of speculation. An examination of the various classes of superficial deposits present has led some observers to postulate glaciation of the district: some, however, have favoured the idea of submergence, while others maintain that the drift represents the remains of solid strata formerly extending over the area.

A comprehensive review of the literature dealing with the subject is given by J. W. Gray,[1] from whose papers one gathers that Buckland was the first to give attention to the area, and in 1821 [2] recorded the presence of drift in the Vale of Moreton, which he assumed to have been deposited by a stream from the north passing down the valley of the Evenlode into that of the Thames. This view is substantially correct, though Buckland, after the manner of his time, attributes the agency of transportation of the material to " the last great deluge that has overwhelmed the earth."

In dealing with traces of northern drift that occur on the uplands of the Cotteswolds, Lucy [3] suggests that their presence is due to the agency of ice. The red-brown clay with northern pebbles that occurs so commonly as an infilling of surface fissures in the limestones he terms ' Boulder Clay,' an expression which does not appear to have been accepted by contemporary and some later writers, who disclaim, without giving adequate reasons for doing so, that the presence of clay with northern pebbles in the fissures affords evidence of glaciation.[4] In some cases, spreads of boulder-clay rightly diagnosed by Lucy, have been regarded as clayey soils, resulting from the decomposition of calcareous beds *in situ*.

The proximity of the northern ice to the Cotteswolds is generally accepted as being responsible for the presence of northern pebbles in the area, but the southern limit of the Boulder Clay has not been traced with any degree of certainty in the western part of England. It is generally assumed to have followed roughly the northern flank of the Thames valley and to have extended westward in a curve around the northern ends of Edge Hill, the Cotteswolds and Bredon Hill, all of which have hitherto been regarded as barriers which

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[1] *Proc. Cotteswold Nat. Field Club*, vol. xvii, 1910-12, pp. 257-274; vol. xx, 1919, pp. 99-141.
[2] *Trans. Geol. Soc.*, vol. v, 1821, pp. 516-544.
[3] *Proc. Cotteswold Nat. Field Club*, vol. vi, 1872, p. 19; vol. vii, 1878, pp. 50-61; vol. x, 1889, p. 7.
[4] Woodward, H. B., *Geol. Mag.*, 1897, p. 487; Gray, J. W., *Proc. Cotteswold Nat. Field Club*, vol. xx, 1919, p. 109.

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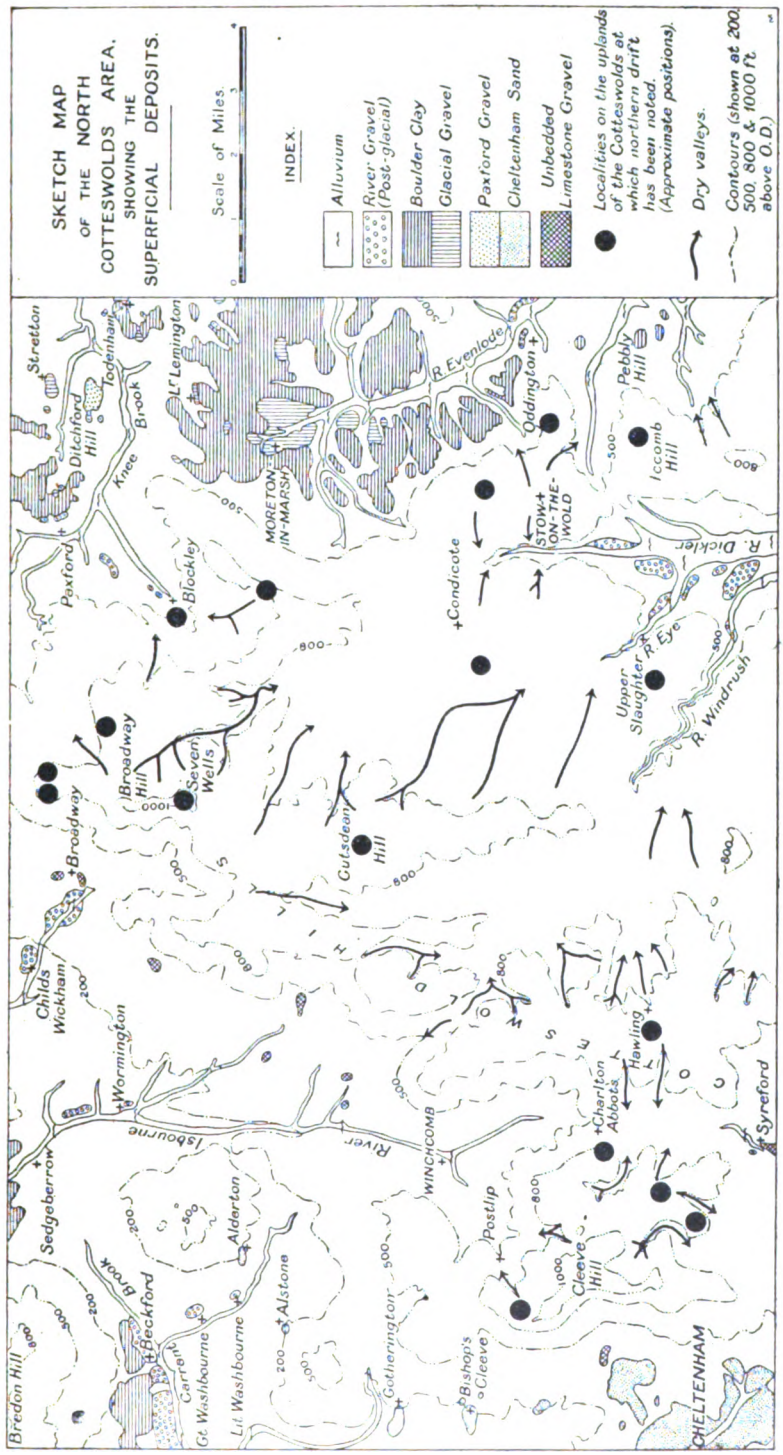

FIG. 1.

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arrested the southward progress of land glaciation. Woodward, however, on the evidence of sections, at Mickleton and Aston Magna, recorded by Gavey in 1853, has suggested the possibility of a tongue of boulder-clay projecting southward into the Vale of Moreton,[1] and Dr. C. Callaway recognised Glacial Clay on the Cotteswolds at Tangley as well as in the valley at Milton-under-Wychwood.[2]

A recent survey of the drift of the district covered by the one-inch Ordnance map Sheet 217 (Moreton-in-Marsh) shows that the glacial deposits definitely form the bulk of the superficial deposits of the area. Boulder-clay and glacial gravel occur extensively in the Vale of Moreton and extend southward along the valley of the Evenlode, while on the western side of the area boulder-clay occurs to the east and south of Bredon Hill. Drift deposits of local origin are not extensive but their relation to the Glacial deposits is in most cases a matter of certainty.

The Vale of Evesham.—In that part of the Vale that lies between Bredon Hill, Broadway and Cheltenham there are four types of deposits:—(1) Unbedded Limestone Gravel, (2) 'Cheltenham Sand' associated with limestone-gravel, (3) Boulder Clay, (4) River Gravel (post-Glacial).

1.—The Unbedded Limestone Gravel consists of angular and subangular debris, from the hills, accumulated on the lower slopes generally at about the 300-ft. contour. It is composed entirely of local material and shows no sign of bedding. The matrix, which forms a small proportion of the whole, is mainly comminuted limestone material. This deposit was probably a source of supply of the limestone constituent of the Cheltenham Sand and the river-gravels, though some of the spreads of the Unbedded Gravel may be of later date.

2.—The Cheltenham Sand is mainly a pale buff quartzose sand with layers of limestone-gravel. The sand is coarser than any known Jurassic sand in the neighbourhood and on the evidence of the suite of heavy minerals yielded, Dr. H. H. Thomas infers that the Trias furnished most of the material[3]; the pebbles present however are all of local origin. This deposit covers a large area at Cheltenham and occurs in small patches at Bishop's Cleeve, Gotherington, Alstone and Alderton. These occurrences are at a uniform level of 200 ft. above O. D. though in the Cheltenham neighbourhood, where the deposit attains its greatest thickness, it rises to higher levels.

3.—The Boulder Clay occurs below the 200-ft. level in patches north of Sedgeberrow and at Beckford, while the intervening ground is strewn with *remanié* drift. The clay is not exposed in any section here but the red loamy soil with northern pebbles and boulders is evident on the surface of cultivated areas.

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[1] *Op. cit.*, p. 487.
[2] *Geol. Mag.*, 1905, pp. 216-219.
[3] Richardson, L., 'Memoir Explanatory of a Map of a Part of Cheltenham,' *Proc. Cotteswold Nat. Field Club*, vol. xvii, 1910-12, p. 305.

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4.—The post-Glacial River Gravel occurs at Broadway, Childs Wickham, Wormington, the Washbournes and Beckford. It consists of current-bedded sand and gravel, the latter composed mainly of limestone pebbles but with some northern material. At Beckford in the valley of the Carrant Brook this gravel lies directly on the boulder-clay.

The Vale of Moreton.—Here the deposits are (1) Paxford (limestone) Gravel, (2) Glacial Gravel, (3) Boulder Clay, and (4) River Gravel (post-Glacial).

1.—The Paxford Gravel, a compact-bedded deposit of limestone fragments, underlies the Glacial deposits and contains no northern pebbles. At Paxford and Ditchford Hill it is entirely of local origin without quartz sand. At Paxford the gravel is overlain by boulder-clay, here a homogeneous red-brown plastic clay with northern pebbles and boulders, while fissures in the gravel at Ditchford Hill contain similar clay and pebbles. Near Great Wolford, 1½ miles east of Lower Lemington, the gravel of this period resembles the Cheltenham Sand, having a large proportion of quartz sand with layers of limestone-gravel. This is overlain by at least 10 ft. of glacial gravel.

2.—Glacial Gravel occurs at Mickleton, Stretton, Todenham, Wolford, around Moreton-in-Marsh, and a mile to the east, at the Four Shire Stone. At Stretton it consists of coarse pink current-bedded sand with thin streaks of Bunter quartzite and quartz pebbles and some small subangular flints. It is overlain by boulder-clay which is pocketed irregularly into the upper surface. The spreads at Todenham and Wolford are similar. The Moreton gravel[1] is typical glacial gravel, the upper part of which has been disturbed by the over-riding ice, giving rise to a vertical arrangement of some of the pebbles.

3.—Boulder Clay once extended as a practically continuous sheet at a level of 400-450 ft. O.D. down the Vale of Moreton but has since been dissected by the Knee Brook, the Evenlode and its tributaries. It occurs between Paxford and Stretton and at Todenham, and covers practically the whole of the floor of the Evenlode valley from Lower Lemington to Oddington. Southward of this the clay occurs in smaller patches near Bleddington and at Pebbly Hill. It has been recorded as far south as Milton-under-Wychwood.[2] Sections near Paxford show a homogeneous plastic red-brown or purple clay with scattered northern stones in which Bunter pebbles, quartz and flint predominate. The Bunter quartzite and the quartz usually occur as small pebbles but boulders are of frequent occurrence; the flints also are mainly small but some large unworn specimens are not uncommon. The lower part of the Boulder Clay, as seen at Mickleton, at Black Downs, 1½ miles east-by-north of Paxford, near Paxford and at Stretton consists in places

[1] Reade, T. M., S. S. Buckman and C. Callaway, *Proc. Cotteswold Nat. Field Club*, vol. xiv, 1903, pp. 111-118.
[2] Callaway, C., *op. cit.*

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of a chaotic mass of blocks of local limestone up to a foot or more across, mixed in a clayey matrix with smaller northern stones and rafts of the red plastic clay. In all localities in which boulder-clay and glacial gravel occur, the former overlies the latter.

4.—The post-Glacial River Gravels occur in the valley of the Knee Brook at Blockley and in the valleys of the Dickler, Windrush and Eye to the south of Stow-on-the-Wold. These are mainly limestone-gravels, and owing to their positions in valleys separated from the main spreads of boulder-clay by high ground, they do not contain much northern material, though the deposits south of Stow-on-the-Wold are reported to contain a few scattered flint fragments. At Oddington, however, the river gravels of the Evenlode are well bedded and contain a fair proportion of quartz sand as well as an abundance of northern stones.

The Uplands.—The northern part of the Cotteswolds, does not appear to have been covered with any considerable thickness of boulder-clay, but the fact that the northern ice rode up over the hills is evident from the numerous recorded occurrences of northern pebbles on the high ground, and the infillings of red-brown clay with northern pebbles that are frequently to be seen in fissures in the limestones, as at Tangley (625 ft. above O.D.) and Martin's Hill (600 ft. above O.D.), a mile east of Stow-on-the-Wold and elsewhere. Known occurrences of northern drift on the high ground extend as far south as Tainton Down, near Burford. A deposit of clay with northern stones occurs at Hill Farm (700 ft. above O.D.) a mile west of Upper Slaughter,[1] and it is possible that there are unrecorded occurrences elsewhere. Northern pebbles sufficient to cobble the path at the Snowshill Road Lodge at Springfield are said to have been collected on the fields between the Lodge and Seven Wells (1,048 ft. above O.D.).

Further evidence of glaciation of the uplands is afforded by the fact that many of the exposures in the limestones show but little weathered rock; this according to Woodward is favourable though not conclusive evidence of glaciation.[2] Where the weathering extends to a depth of several feet, however, the loosened slabs of limestone are much disturbed, as at Martin's Hill. Moreover the slopes of the Cotteswolds are covered, in many localities with accumulations of rubble which at Syreford has a matrix of brown loamy clay. This rubble probably accumulated on the hill slopes during times of thaw. Again many of the valleys cutting through the limestone are now dry. They commence in the higher parts of the country where no source of water-supply is now available and, from a flat plain, plunge steeply down into deep gorge-like valleys, dry for a considerable length in their upper reaches. These valleys may be due, in part, to solution of the limestone, but it is possible that water from a melting snow- or ice-cap may have played a part

[1] Gray, *op. cit.*, vol. xvii, 1911, pp. 260-261.
[2] *Op. cit.*, p. 490.

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in the formation of some of them, for example, the Postlip valley, and that which commences near the slopes of Broadway Hill on the western side of the Cotteswolds and runs in a direction south-south-east as a steep-sided valley which is dry for about five miles before it becomes occupied by the River Dickler.[1]

Conclusion.—There is no suggestion of the glaciation of the Cotteswolds having been severe; the boulder-clay in the Evenlode valley, though widespread, does not appear to exceed 8 ft. in thickness, and the presence of boulders of limestone in the base of the boulder-clay, as at Mickleton, Black Downs and Stretton, indicates that accumulations of disintegrated local rocks contained in the local sedentary ice-sheet, though absorbed by the advancing ice-sheet from the north, had not travelled sufficiently far to become incorporated in the higher part of the drift. The absence of thick or large spreads of boulder-clay on the uplands can be accounted for by the probability that only the higher portions of the ice-sheet over-rode the hills.

[1] See also Buckland, *Trans. Geol. Soc.*, vol. v, 1821, p. 523, footnote.

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X.—A NOTE ON 'PTYGMATIC FOLDING' IN THE SUTHERLAND GRANITE-COMPLEX

By H. H. Read, D.Sc., A.R.C.Sc.

Text-figures 1 and 2.

During his life-study of the Finnish granite-complexes, Professor J. J. Sederholm has suggested many new terms for the remarkable structures and associations there encountered; among these is *ptygmatic folding*. A tracing (Fig. 1, upper) of an illustration from the latest publication of Sederholm will serve to show the nature of ptygmatic folding better than words.

In a long series of investigations[1], Sederholm has discussed the origin of this structure. His results may be briefly summarised as follows. Ptygmatic folding is illustrated typically by acid veins connected with granite injections. From the absence of metamorphism in the minerals of the veins, it is considered that the consolidation of the vein took place, in general, subsequent to the folding. The veins were probably all originally straight and filled plane fissures in the rock. Their characteristic folding is due to undulating movements in the softened or semi-molten country-rock, this softening arising from the associated granite injections.

Other observers of what are certainly ptygmatically folded veins have not accepted Sederholm's explanation. Among these, two divergent opinions are maintained; the first due to P. J. Holmquist, sees in the formation of ptygmatically folded veins the operation of ultrametamorphism; the second, advanced by L. Milch, B. Sander, J. E. Spurr and others, would explain ptygmatic structure as due to folding of 'Alpine type' produced by mountain-building movements after the consolidation of the vein-substance.

While he admits the local occurrence of injection-rocks related to definite granite intrusions, P. J. Holmquist[2] regards the more regional veined rocks (Adergesteine) as the result of ultrametamorphism,—the production from the substance of the rock undergoing regional metamorphism of its own secreted endogenous pegmatites. Under the conditions of ultrametamorphism such secreted pegmatites take up a contorted form in the plastic country-rock, which though plastic enough to follow the plications of the pegmatite, is not itself deformed in a corresponding manner. Among the other group of observers, L. Milch[3] concludes that the form of

[1] Sederholm, J. J., 'Om Granit och Gneis', *Bull. Com. Géol. Finlande*, No. 23, 1907; 'Uber ptygmatische Faltungen,' *Neues Jahrb.* B. Bd. 36, 1913, p. 491; 'On Migmatites and Associated pre-Cambrian Rocks of Southwestern Finland, I—the Pellinge Region,' *Bull. Com. Géol. Finlande*, No. 58, 1923, and 'II—the Region around the Barosundsfjard W. of Helsingfors, etc.,' *ibid*, No. 77, 1926.

[2] Holmquist, P. J., 'Typen und Nomenklatur der Adergesteine,' *Géol. Foren. Forh.*, xliii, 1922, p. 612; 'Om Pegmatitpalingenes och ptygmatisk Veckning,' *ibid.*, xlii, 1920, p. 191.

[3] Milch, L., 'Ueber dynamometamorphe Erscheinungen an einem nordischen Granitgneis,' *Neues Jahrb.*, ii, 1900, p. 39.

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ptygmatic veins in a German erratic originating from Scandinavia is obviously secondary, produced by pressure affecting the rock after its solidification ; where the veins in this specimen are hazy, Milch considers them to have been partly obliterated by the movements. Again, B. Sander,[1] after visiting the Finnish examples, maintained that they were the results of folding of " Alpine type " and could be matched in Alpine specimens unassociated with regional injection or anatexis. Recently, too, J. E. Spurr[2] has described and figured from Manitoba typical ptygmatic veins (accepted as such by Sederholm) which he believes to be the effect of gneissic deformation, resulting in the folding of each vein " back on itself like an accordion,

FIG. 1.—*Veins showing 'Ptygmatic Folding,' from Finland (above) and Sutherland (below).*

regularly, showing a uniform compression at right angles to the gneissic deformation" The compression of these veins and the gneissic deformation are thought to result from the doming-effect of a later granite.

Veins showing what appears to be typical ptygmatic folding have been repeatedly encountered by the writer in the great Sutherland granitic injection-complex[3]. A Sutherland vein showing ptygmatic

[1] Sander, B.,' Studienreisen im Grundgebirge Finlands,' *Verh. d.k.k. geol. Reichsanst.*, 1914, p. 82.

[2] Spurr, J. E., ' The Ore Magmas,' vol. i, 1923, pp. 164-70.

[3] Only part of this complex has been described. See J. Horne and E. Greenly, ' On Foliated Granites and their Relations to the Crystalline Schists in Eastern Sutherland,' *Quart. Journ. Geol. Soc.*, vol. lii, 1896, pp. 633-648 ; and H. H. Read, in ' The Geology of Golspie, Sutherland ' (Explanation of Sheet 103), (*Mem. Geol. Surv. Scot.*), 1925, pp. 21-40 ; and in ' The Geology of Strath Oykell, etc.' (Explanation of Sheet 102), (*Mem. Geol. Surv. Scot.*), 1926, pp. 148-52. The Geological Survey Memoir on Sheets 108 (Altnaharra) and 109 (Kinbrace), now in preparation, deals with some 300 square miles of this complex.

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folding is figured in Fig. 1 and presents no essential differences from the Finnish ptygmatic veins; this figured vein is not an exceptional type. The lavish illustration of Sederholm's memoirs permits of detailed comparison between the Finnish and Scottish complexes; the similarity between the various structures of the two complexes has already been pointed out.[1] In the writer's opinion it is certain that veins showing what Sederholm calls ptygmatic folding are common in the Sutherland complex.

The Sutherland veins occur chiefly in rocks of the Moine Series and then in the siliceous and semipelitic granulites of that Series; more rarely typical ptygmatically folded veins are found in the hornblende-schists that represent basic igneous rocks of pre-metamorphism age. The Moine granulites show, in general, a marked banded structure by variation in the amount of biotite. With rare exceptions, the foliation agrees with this original sedimentary banding. The veins consist of quartz and felspar; their materials show no foliation, no directed structures, no cataclasis. The relations of these veins to the foliation of the Moine rocks can be seen from the series of sketches given in Fig. 2 and need not be detailed. Special points of these sketches will be emphasised in the following discussion.

Consideration of the Sutherland veins leads to the conclusion that none of the explanations of ptygmatic folding already summarised is applicable to them.

First may be taken the dynamometamorphic interpretation of Milch, Sander and Spurr. The Sutherland veins show no metamorphic phenomena; they belong to an epoch believed to be later, though, it is true, not much later, than the production of the Moine metamorphism. There is no agreement between the vein-folding and the host-folding, as can be seen by a glance at practically any of the sketches in Fig. 2. The dynamometamorphic interpretation implies that ptygmatic veins were once straight (or rather, plane). Many of the drawings of Fig. 2, such as A, B, E, G, K and M, show at once that the tortuous veins were never plane. Very commonly the Sutherland veins follow faithfully the contortion of the Moine sediments. It might be argued that such veins were folded with the sediments and were originally plane. Apart from the absence of metamorphic phenomena in the veins, the occurrence of vein-systems such as those of sketches E, K, M, N and Q of Fig. 2 shows the impossibility of such folding.

In the second place, the production of ptygmatically folded veins by endogenous secretion during ultrametamorphism, as favoured by Holmquist, is clearly not operative in the Sutherland examples. Quartz secretions and quartzo-felspathic pegmatite-like secretions are well known in many Highland pelitic rock-groups, but are scarce or absent in the normal siliceous and semipelitic granulites of the Moine Series of Sutherlandshire. Further, the clearly intrusive igneous nature of the veins, and their definite association with great

[1] Read, H. H., *loc. cit.*, 1925, p. 33.

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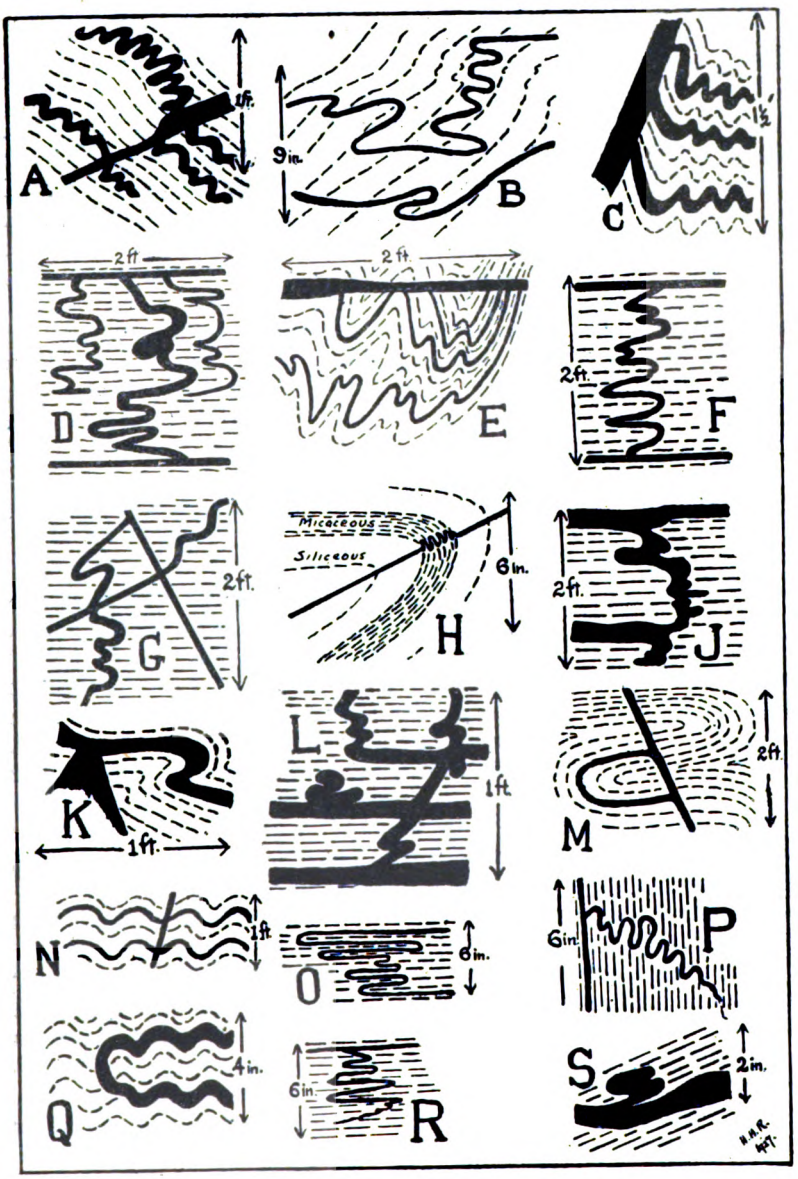

FIG. 2. – *Sketches of vein-systems in the Sutherland Granite-complex.* (*In each sketch, all veins are of the same age.*)

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igneous bodies of unquestionable origin, show that they were not produced by secretion during regional metamorphism. Again, the Moine sediments in which these veins occur differ in few respects from similar sediments outside the complex; their grain-size is slightly larger and they are sometimes tougher and less flaggy; there is, however, no question of their having undergone any ultra-metamorphic change or having attained any degree of plasticity.

Finally, the application of Sederholm's views on ptygmatic folding to the Sutherland veins is difficult from several aspects. Sederholm's supposition that these veins were originally straight (plane) cannot hold for veins such as those of sketches A, B, E, G, K and M of Fig. 2. It is difficult to believe that liquid veins during folding could preserve a uniform breadth, or could be folded on a plan different from that of the host-folding or, in fact, could exist as continuous liquid veins at all. The plane folding of the Moine sediments in which tortuous veins occur differs in no respects from that of similar rocks quite outside the injection-complex; there is no evidence that the veined Moine sediments were ever in a softened or semi-molten condition.

In the writer's opinion, it is evident

(1) that the tortuous veins of Sutherland were never plane.
(2) that their forms are original,
(3) and that they are non-metamorphic.

The term ' folded ' suggests the idea of 'original straightness' of the thing folded. Thus, certain tortuous veins having been described as ptygmatically folded, they should originally have been in general straight. In this measure, Sederholm's term ' ptygmatic folding ' is not for general use, even for exactly similar structures; its employment denotes that the user is prepared to demonstrate that the structures under discussion are secondary. It is the writer's opinion, derived from a fairly complete survey of the available literature, that in no case has the original planeness of 'ptygmatically folded' veins been demonstrated. The original tortuosity of similar veins in Sutherland is a matter of observation.

Certain features of the occurrence of the Sutherland veins are worthy of emphasis. The dominant factor in the production of tortuosity (not reproducing that of the original folding of the country-rock) appears to be the resistance of the rock concerned to plane-fissuring. Time and again, veins have been observed that are perfectly plane ' *lits* ' when parallel to the bedding or foliation, but show marked tortuosity when they leave these controlling guides, (see sketches D, F, J, L, O, P and R of Fig. 2). The same control is evident in the vein shown in Sketch H; this vein is plane when traversing the plane-fissuring siliceous granulites but is tortuous in the more resistant micaceous band. The tortuous side-veins shown in Sketch A likewise traverse micaceous bands in the granulite. The absence of easily opened plane channels for the injected material thus affects the form of the veins. Injection into a structureless country-rock not readily giving plane fissures should, on this

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interpretation, be especially marked by the occurrence of tortuous 'ptygmatically folded' veins. In the immediate neighbourhood of an injection-complex the country-rock undergoes injection-metamorphism which, whether it be of thermal, metasomatic or mixed type, produces a partial loss of directed structures and the formation of rocks more massive than those outside the complex. Thus, in Sutherland, 'ptygmatically folded' veins are common in the 'hardened' rocks of the injection-complex proper whilst, outside this, when they occur they do so more often in the relatively massive hornblende-schists than in the associated plane-fissuring Moine sediments.

An examination of the published work of J. J. Sederholm shows, in the writer's opinion, that the typical ptygmatic folding of the Finnish complexes occurs in veins traversing relatively structureless rocks not readily giving plane fissures. Thus, for example, Sederholm remarks of his type ptygmatite locality that "the surrounding schist shows a hälleflint-like appearance and is apparently more massive than the rest of the schist"[1]; again, in the Helsingfors region, the rock containing the veins is often a hornblende-gneiss or metabasite[2]. Moreover, veins that are straight in 'meta-andesite, that shows a better preserved primary texture, occasionally exhibit, when they reach hälleflint-like rock, the peculiar kind of folding which the author has called ptygmatic'[3]. Sederholm concludes that the hälleflint-like character of the associated country-rock is the expression of its partial plasticity during the ptygmatic folding. The present writer would suggest that the hälleflint-like character of the country-rock, resulting from injection-metamorphism, is as in the Sutherland cases the prime cause of the original tortuous form of the injections.

In conclusion, the following points emerge from the examination of the Sutherland tortuous veins.

(1) Sutherland veins, resembling the ptygmatic veins of Sederholm, are considered to have their original form; they were never plane.

(2) They are connected neither with ultrametamorphic nor dynamometamorphic phenomena; they are true igneous injections, showing no metamorphic characters.

(3) Their tortuous form, it is suggested, results from the resistance to plane fissuring of the country-rock, a resistance arising from the mineralogical and structural habit of the rock, the latter being in many cases the effect of injection-metamorphism.

(4) The term 'ptygmatic folding' denotes that the user believes that veins showing this folding were originally straight; the term should be limited to such cases.

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[1] *Neues Jahrb.*, B.Bd. 36, 1913, p. 495.
[2] *Ibid.*, p. 502.
[3] *Bull. Com. Géol. Finlande*, No. 58, 1923, p. 85.

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XI.—THE ADISHAM BORING, KENT

By J. PRINGLE.

During the passage of the memoir on ' The Concealed Mesozoic Rocks in Kent,' (*Mem. Geol. Surv.*, 1923) through the press, a boring was in progress at Adisham, and excepting a few references to it we were unable to give in that volume details of the rocks encountered in the exploration. Through the kindness of Mr. E. O. Forster Brown, permission has now been granted to publish an account of the Mesozoic rocks and those older than the Coal Measures.

Borehole about 90 *yds. N. of church at Adisham*, 1922-3. *About* 133 *ft. above Ordnance Datum*

		Thickness. Ft.	In.	Depth. Ft.	In.
	Soil	1	0	1	0
Chalk 777 ft.	White Chalk with flints. No cores ...	517	0	518	0
	Chalk. No cores	82	0	600	0
	Soft white chalk, core samples from various depths between 600 ft. and 659 ft.	59	0	659	0
	Greyish-white chalk with *Schloenbachia varians, Nautilus elegans* and *Inoceramus crippsi*. At base a line of greenish-black phosphatic nodules... ...	86	0	745	0
	Grey marly chalk with a band of dark silty clay between 759 ft. and 762 ft.	33	0	778	0
Gault	Dark clays ; no cores	168	0	946	0
Sandgate Beds 8 ft. 5 in.	Soft brown glauconitic sand, hard band at top	6	5	952	5
	Dark grey clayey sand	2	0	954	5
Atherfield Clay 10 ft. 4 in.	Firm marly clay of a rich chocolate brown colour. From 961 ft. downwards the clay contains numerous small polished phosphatic grains and rounded fragments of bone. Clay rests on an irregular surface of a Wealden limestone	10	4	964	9
Wealden 30 ft. 3 in.	Thin bluish-grey limestone with Cyprids. The upper surface shows worm-burrows infilled by the basal bed of Atherfield Clay	—	3	965	0
	Slaty-grey clay with Cyprids and fish fragments	—	6	965	6
	Bluish-black and grey silty clays with a thin grey earthy limestone at 967 ft. Cyprids and fish remains abundant...	28	6	994	0
	Hard pale grey fine grained sandstone with many fragments of lignite, about	1	0	995	0

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Unconformity.

		Thickness. Ft.	In.	Depth. Ft.	In.
Oxford Clay 82 ft.	Grey marly clay with a few hard marly bands. *Quenstedtoceras* fragments seen at 1,030 ft.; cores imperfect ...	44	0	1,039	0
	Greyish-white limestone with *Rhynchonella sp.*	1	0	1,040	0
	Brownish marly clay, becoming sandy at base. *Astarte spp.* and *Cucullaea* cf. *subtetragona* (Mor.)	36	0	1,076	0
	Brownish sandy shelly marl crowded with crushed shells of *Pseudomonotis sp. nov.*	1	0	1,077	0
Kellaways Rock 33 ft. 4 in.	Brownish grey calcareous sandrock with many small bits of bright polished ironshot	2	3	1,079	3
	Soft brown sandrock with many grains of polished ironshot; poor cores; 1½ ft. of core representing	6	8	1,085	11
	Greenish-brown somewhat soft ironshot sandrock; poor cores, 2 ft. of core representing	12	8	1,098	7
	No core	6	7	1,105	2
	Greenish-brown sandy marl with bright grains of polished ironshot plentifully scattered throughout matrix. *Gryphaea*, etc., at base, core imperfect...	5	2	1,110	4
Cornbrash 19 ft. 8 in.	Grey Clay		8	1,111	0
	Greyish-white finely oolitic limestone, becoming marly below	9	0	1,120	0
	Dingy grey oolitic shelly limestone; casts of the shells filled with coarsely crystalline calcite, limestone mixed with dark marl at base	4	0	1,124	0
	Hard cream coloured limestone sprinkled with small brown grains of ironshot...	5	0	1,129	0
	Dark grey muddy nodular limestone with dull brown specks of ironshot. *Rhynchonella major* Desl. and *Terebratula sp.*	1	0	1,130	0
Forest Marble 8½ ft.	Greenish black marly clay with a 6-inch band of greenish clay at 1,133 ft. 5 inches	4	0	1,134	0
	Blotchy grey marly clay with many shells and plant fragments in lower part	2	0	1,136	0
	Creamy oolitic limestone, irregularly indurated, and mixed with greenish clay	—	6	1,136	6
	Dark marly shelly clay with *Epithyris marmorea* (S. Buckman)	2	0	1,138	6
Great Oolite Series 61½ ft.	Hard bluish-grey oolitic limestone with a few thin marly bands	60	6	1,199	0
	Black shelly clay passing down into a dark sandy clay with pebbles of limestone. Bed indurated at base. *Homomya gibbosa* (J. Sow.) and *Mytilus furcatus* Mor. and Lyc. ...	1	0	1,200	0

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			Thickness. Ft. In.	Depth. Ft. In.
		Unconformity.		
Lias 12½ ft.	Upper 4 ft.	Dingy grey marly clay with *Dactylioceras spp.* and small crushed *Rhynchonellae*	4 0	1,204 0
	Middle 5 ft.	Hard grey limestone, somewhat muddy in places; *Pecten inaequivalvis* J. Sow., etc.	4 0	1,208 0
		Dark sandy clay with *Belemnites sp.*	1 0	1,209 0
	Lower 3½ ft.	Smooth silty black clay with a layer of pebbles at base. *Nuculana sp.* (B) etc.; resting on Coal Measures	3 6	1,212 6
Coal Measures			2,025 3	3,237 9
Carboniferous Limestone			27 0	3,264 9

Generally, the section of Mesozoic rocks is the same as that provided by the Fredville boring and the Snowdown shafts, excepting that the Lower Corallian beds are cut out at Adisham, where the Wealden Series rests on a horizon high in the Oxford Clay. The unconformable relationship of the Cretaceous rocks to the underlying Jurassic formation is thus clearly demonstrated.

The presence of the three divisions of the Lias in thin development, however, was to some extent unexpected, and it is now evident that the boundary of the formation must lie on the north-eastern side of the railway between Snowdown and Adisham. In the excellent cores it was possible to assign a separate thickness for each subdivision.

Rocks of Lower Carboniferous age were entered at the depth of nearly 3,238 ft. They consist of dark grey bituminous and porcellaneous limestones; and although no fossils were found, the lithological characters of the beds suggest that the limestones are probably the same as those of S_1—S_2 age found at Elham. In the Adisham boring the upper surface of the limestone is exceedingly irregular, and the hollows are filled with clays of the overlying Coal Measures.

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XII.—ON FOSSILS FROM THE COAL MEASURES OF KENT

By J. PRINGLE and R. CROOKALL, PH.D.

In the *Summary of Progress* for 1916 the details of the Coal Measures passed through in three deep borings in Kent were given in an Appendix.[1] A small number of fossils, identified at the time of collecting, were included in the description of the rocks, and it was stated that, as the fossils were still under investigation, publication of the full results must be deferred. We therefore propose to give these details in the following pages. Of the plants collected, the majority were named by the late Dr. R. Kidston,[2] but all of them have since been revised by one of us, whilst the other author, the collector of all the material, is responsible for the identification of the molluscan and other remains.

No marine shells were noted in any of the borings. A large fragment of a species of *Eurypterus* was found at Elham, and, although it cannot be specifically determined, it is worthy of placing on record on account of the rarity of this genus in the British Coal Measures. The plants collected form a representative suite, and include a number of rare and interesting forms. Among them is a single piece of petrified wood which is identified as *Dadoxylon sp.* In this connexion, it is of interest to note that similar petrified plant-remains are known both from the Bristol and Somerset and the South Wales Coalfields.[3]

Elham Borehole

PLANTS

	Depth in ft.
Pteridospermeae and *Filicales*	
Alethopteris lonchitica (*Schloth*).	2,254
Lonchopteris rugosa *Brongt.*	1,720
Mariopteris nervosa *Brongt.*	1,975
Neuropteris gigantea *Sternb.*	1,845, 2,030
,, heterophylla *Brongt.*	2,030
,, microphylla *Brongt.*	2,032
,, tenuifolia (*Schloth.*)	2,118, 2,122
,, sp.	1,975, 2,030, 2,176, 2,254
Sphenopteris sp.	2,162
Lycopodiales	
Lepidodendron sp.	1,706
Lepidostrobus anthemis (*König*)	1,706, 1,709
Sigillaria laevigata *Brongt.*	1,726
,, sp.	1,634
Stigmaria ficoides (*Sternb.*)	1,744, 2,044, 2,196
,, sp.	2,283

[1] Pringle, J., 'On deep borings for Coal and Ironstone at Bere Farm, Elham, and Folkestone, Kent,' 'Summary of Progress' for 1916 (*Mem. Geol. Surv.*), 1917, pp. 34-40.

[2] A preliminary list of these records was printed in the 'Summary of Progress' for 1918 (*Mem. Geol. Surv.*), Appendix 2, p. 46.

[3] Crookall, R., 'On *Sutcliffia lilliei* n. sp.,' 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, pp. 161-167.

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	Depth in ft.
Equisetales	
Asterophyllites equisetiformis (*Schloth.*)	1,720
Calamites suckowi *Brongt.*	1,944, 1,946, 2,074
,, undulatus (*Sternb.*)	1,820
Calamitic cone	2,190
Sphenophyllales	
Sphenophyllum sp.	2,160
Cordaitales	
Cordaites principalis (*Germar*)	1,720
Semina incertae sedis	
Carpolithes membranaceus *Göpp.*	1,720
ARTHROPODA	
Eurypterus sp.	2,251

Bere Farm Borehole

PLANTS

	Depth in ft.
Pteridospermeae and *Filicales*	
Alethopteris davreuxi (*Brongt.*)	1,880-1,886, 2,055-2,056
Aphlebia sp.	1,994
Asterotheca miltoni (*Artis*)	1,880-1,886, 2,684-2,690
,, *cf.* miltoni (*Artis*)	1,880-1,886, 1,994
Cyclopteris sp.	2,944
Linopteris münsteri (*Eichw.*)	2,944
Mariopteris nervosa *Brongt.*	2,684-2,690
,, sp.	2,684-2,690
Neuropteris macrophylla *Brongt.*	1,880-1,886
,, *cf.* macrophylla *Brongt.*	1,880-1,886, 1,970
,, microphylla *Brongt.*	2,550, 2,911
,, missouriensis *Lesqx.*	2,684-2,690
,, obliqua (*Brongt.*)	2,630-2,635
,, ovata *Hoffm.*	1,880-1,886, 2,550, 2,684-2,690
,, *cf.* ovata *Hoffm.*	1,880-1,886
,, rarinervis *Bunb.*	1,975, 2,348, 2,550, 2,630-2,635, 2,911
,, *cf.* rarinervis *Bunb.*	1,880-1,886, 1,975, 2,684-2,690, 2,924, 2,944
,, scheuchzeri *Hoffm.*	1,880-1,886, 1,970, 2,055-2,056, 2,630-2,635, 2,684-2,690, 2,911, 2,924
,, *cf.* scheuchzeri *Hoffm.*	1,970
,, sp.	2,630-2,635, 2,684-2,690, 2,911, 2,944
Odontopteris lindleyana *Sternb.*	2,944
,, *cf.* lindleyana *Sternb.*	1,880-1,886, 2,005-2,008
Pecopteris *cf.* pennaeformis *Brongt.*	2,684-2,690
,, *cf.* richardsoni *D. White*	2,684-2,690
,, (Cyatheites sp.)	2,550, 2,684-2,690
,, sp.	1,880-1,886
Ptychocarpus *cf.* unitus (*Brongt.*)	1,880-1,886
Sphenopteris *cf.* neuropteroides *Boulay*	1,994
Lycopodiales	
Sigillaria tessellata *Brongt.*	2,684-2,690
Stigmaria ficoides (*Sternb.*)	1,864, 2,754
Equisetales	
Annularia sphenophylloides (*Zenker*)	1,880-1,886, 2,684-2,690, 2,944
,, stellata (*Schloth.*)	1,880-1,886
Calamites suckowi *Brongt.*	1,880-1,886, 1,926, 2,550
,, *cf.* suckowi *Brongt.*	1,990
,, sp.	1,920, 2,684-2,690
Palaeostachya elongata *Presl*	2,005-2,008

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	Depth in ft.
Sphenophyllales	
Sphenophyllum emarginatum *Brongt.* ...	1,880-1,886, 2,005-2,008
,, sp.	2,684-2,690
Cordaitales	
Cordaites sp.	1,880-1,886, 2,085
Dorycordaites palmaeformis (*Göpp.*)	2,911
Antholithus sp.	1,880-1,886
Cordaianthus sp.	2,081
Semina incertae sedis	
Samaropsis arberi *Kidst.* [MS.] [1]	1,920
Cf. Trigonocarpus sp.	1,880-1,886

Boring at Tower Brickworks, Folkestone

PLANTS

	Depth in ft.
Pteridospermeae and *Filicales*	
Alethopteris aquilina (*Schloth.*)	1,723-1,725, 2,072
,, serli (*Brongt.*)	1,690, 1,715, 1,723-1,725
Asterotheca miltoni (*Artis*) ...	1,723-1,725, 1,980, 2,950-2,955, 3,095-3,097
Cf. Asterotheca miltoni (*Artis*)	2,990-2,993
Cf. Asterotheca oreopteridia (*Schloth.*)	1,760
Dactylotheca plumosa (*Artis*)	1,620
,, ,, *forma* dentata *Bgt. pro sp.*	3,095-3,097
Cf. Eremopteris artemisaefolia (*Sternb.*)...	1,590, 1,636 1,996, 2,914
Eupecopteris bucklandi (*Brongt.*)	2,950-2,955
Mariopteris nervosa (*Brongt.*)	1,647-1,649, 1,784-1,787
,, sp.	1,647-1,649
Neuropteris *cf.* callosa *Lesqx.*	2,780
,, fimbriata *Lesqx.*	1,792-1,795, 1,846
,, flexuosa *Sternb.*	1,647-1,649, 1,837-1,840, 1,846
,, flexuosa *Sternb. var.* rotundifolia (*Bgt.*) ...	1,647-1,649
,, gigantea *Sternb.*	1,846
,, *cf.* grangeri *Brongt.*	2,760
,, ovata *Hoffm.*	1,792-1,795
,, rarinervis *Bunb.* ...	1,557, 1690, 1,708-1,710, 1,723-1,725, 1,780, 1792-1,795, 1,873, 2,242, 2,790, 2,765
,, scheuchzeri *Hoffm.* ...	1,548-1,552, 1,647-1,649, 1,780, 1,784-1,787, 1,792-1,795, 1,846, 1,980, 2,038, 2,044, 2,635-2,640, 2,990-2,993, 3,290, 3,298.
,, *cf.* scheuchzeri *Hoffm.*	1,647-1,649
,, sp. ...	1,647-1,649, 1,837-1,840, 1,846, 2,760, 2,765, 2,806. 2,950-2,955, 2,990-2,993, 3,286, 3,295
Odontopteris *cf.* lindleyana *Sternb.*	1,760
Pecopteris (Cyatheites sp.) ...	1,548-1,552, 1,590, 1,764, 2,044, 3,290
,, sp.	1,678, 2,990-2,993
Renaultia chaerophylloides (*Brongt.*)	1,768, 1,980
Urnatopteris herbacea (*Boulay*)	1,768
Sphenopteris striata *Gothan*	1,780, 2,072
,, sp.	1,585, 1,792-1,795
Lycopodiales	
Lepidodendron fusiforme *Corda*	1,846
,, rimosum *Sternb.*	1,846
,, sp.	1,784-1,787, 2,030, 2,038

[1] Awaiting publication.

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	Depth in ft.
Lepidophyllum lanceolatum *L. & H.*	1,980
,, majus *Brongt.*	1,792-1,795
,, sp.	1,780
Lepidostrobus anthemis (*König*)	1,780, 3,095-3,097
,, sp.	1,980
Sigillaria sp.	1,487, 2,038
Sigillariophyllum sp.	2,038, 2,635-2,640, 3,095-3,097
Stigmaria ficoides (*Sternb.*)	1,578
,, sp.	3,400
Equisetales	
Annularia galioides (*L. & H.*)	1,747
,, sphenophylloides (*Zenker*)	1,647-1,649, 1,708-1,710, 1,715, 1,723-1,725, 1,873, 1,969, 1,980, 2,826, 2,950-2,955, 3,095-3,097
,, stellata (*Schloth.*)	1,708-1,710, 1,980, 2,284, 2,635-2,640
,, *cf.* stellata (*Schloth.*)	1,780, 2,284
Asterophyllites longifolius (*Sternb.*)	1,660
Calamites suckowi *Brongt.*	1,548-1,552, 1,557, 1,585, 1,620, 1,647-1,649
,, sp.	1,535-1,538, 1,548-1,552, 1,620, 1,784-1,787, 1,816, 2,483, 2,484, 2,890
Stachannularia tuberculata (*Sternb.*)	1,792-1,795
Calamitic cone	1,557, 1,747
Sphenophyllales	
Sphenophyllum emarginatum *Brongt.*	1,647-1,649, 1,980, 2,044
,, majus *Bronn*	1,780
,, sp.	1,590, 1,647-1,649, 1,980
Cordaitales	
Cordaites borassifolius (*Sternb.*)	1,708-1,710, 1,950
,, sp.	1,490, 1,768
Dorycordaites palmaeformis (*Göppert*)	1,748, 1,980
Dadoxylon sp.	2,591
Semina incertae sedis	
Carpolithes membranaceus *Göppert*	1,723-1,725
Holcospermum mammillatum *Lesqx.*	1,647-1,649
Samaropsis arberi *Kidst.*	2,242
,, crassa (*Lesqx.*)	2,242
,, fluitans *Arber* (non Dawson)	1,764
,, reniformis (*Geinitz*)	1,723-1,725
MOLLUSCA, etc.	
Anthracomya phillipsi (*Will.*)	2,019
,, phillipsi ? (*Will.*)	1,886, 2,473
,, tenuis *Davies and Trueman*	1,987, 2,019
,, sp.	2,284
Ostracods	2,019

In 1915, Dr. H. Bolton[1] divided the Coal Measures of Kent into an Upper and Lower Series, and, on lithological and faunal evidence regarded 'The Kent Upper Series as Pennant-Farrington in age, when compared with the Measures of Somerset.' He added, however, that the beds 'are equally Westphalian when compared with the Coal Measures of Belgium and Northern France,' thus, presumably, suggesting a Middle Coal Measure horizon for his Kent Upper Series. Bolton also concluded[2] that 'The Lower Series of

[1] Bolton, H., 'The Fauna and Stratigraphy of the Kent Coalfield,' *Trans. Inst. Mining Eng.*, vol. xlix, 1915, pp. 643-702.
[2] *Op. cit.*, p. 693.

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sandstones and binds have a fauna which, so far as is yet known, is comparable to that of the Vobster, Ashton, and Bedminster Series of the Bristol and Somerset Coalfield,' and he[1] described the beds as 'typically of Lower Coal Measure age.' On floral evidence, Arber,[2] however, referred the upper part of Bolton's Upper Series to the Transition Coal Measures (=the Staffordian Series), and the lower portion of the Kent Coal Measures to the Middle Coal Measures (= the Yorkian Series). The apparent discrepancy between these two results was removed in the discussion on Dr. Bolton's paper, when Wheelton Hind[3] observed that 'the base of the Kentish Coal Measures, . . . did not pass much, if at all, below the horizon of the Knowles Coal of North Staffordshire. There was consequently no contradiction between the palaeobotanical and the faunal evidence.' He was absolutely in agreement with Dr. Arber's views, but on totally different grounds.

The plant and animal remains found in the borings at Elham, Bere Farm and Folkestone, as set forth in the above tables, lend support to the views of Arber and Kidston. Indeed, the presence of strata of high Staffordian age is clearly shown by the fauna of the upper part of the Measures at Folkestone, in which occur abundant examples of *Anthracomya phillipsi* (Will.) in association with *A. tenuis* Davies and Trueman, thus showing that the strata must fall in the lower portion of the Zone of *Anthracomya tenuis* of these authors.[4] The floral evidence is equally convincing. The top 500 feet of the Coal Measures contain a flora which is a mixture of Radstockian and Yorkian plants, and the beds thus belong to the Staffordian Series (Transition Coal Measures). The most frequent of the Radstockian forms are *Neuropteris ovata, N. scheuchzeri, N. rarinervis, N. flexuosa, N. fimbriata,* and *Alethopteris serli,* while of less common occurrence are *Alethopteris aquilina, Dactylotheca plumosa, Asterotheca oreopteridia, Annularia sphenophylloides, A. stellata,* and *Sphenophyllum emarginatum. Urnatopteris herbacea* is known only from the Staffordian Series. With the Radstockian species are found several Yorkian plants, but these are of rare occurrence; they include *Eremopteris artemisaefolia, Renaultia chaerophylloides, Mariopteris nervosa, Sphenopteris striata,* and *Asterophyllites longifolius.* Although the flora is a mixed one, the Radstockian elements largely preponderate, and it is thus evident that the strata belong high up in the Staffordian Series, and can be referred with certainty to the Newcastle-under-Lyme Group.

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[1] *Op. cit.*, p. 668.

[2] Arber, E. A. N., 'On the Fossil Plants of the Waldershare and Fredville Series of the Kent Coalfield,' *Quart. Journ. Geol. Soc.*, vol. lxv, 1909, pp. 21-39; 'On the Fossil Flora of the Kent Coalfield,' *Quart. Journ. Geol. Soc.*, vol. lxx, 1914, pp. 54-81; and 'Studies of the Geology of the Kent Coalfield—Pt. I: The Coal-Measure records of four Borings,' *Trans. Inst. Mining Eng.*, vol. l, 1916, pt. 2, pp. 351-372.

[3] Discussion of Mr. Herbert Bolton's paper on 'The Fauna and Stratigraphy of the Kent Coalfield,' *Trans. Inst. Mining Eng.*, vol. l, 1916, pt. 2, pp. 294-319.

[4] Trueman, A. E., and J. H. Davies, 'A revision of the non-marine Lamellibranchs of the Coal Measures,' *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927, pp. 210-259.

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Recent work by one of the present authors [1] has shown that a typical Yorkian flora is present in the so-called Millstone Grit of the Bristol Coalfield, while there is no indication of a Lanarkian flora, so that the plant divisions represented in the two coalfields may now be compared as follows:

	Kent Coalfield	Bristol Coalfield
Radstockian Series	absent	present
Staffordian Series	present	present
Yorkian Series	present	present
Lanarkian Series	absent	absent

[1] Crookall, R., 'On the Fossil Flora of the Bristol and Somerset Coalfield,' *Geol. Mag.*, vol. lxii, 1925, pp. 403-404.

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XIII.—PALAEOZOIC SPECIES OF *VETACAPSULA* AND *PALAEOXYRIS*

By R. CROOKALL, PH.D.

Plates I, II.

During the year I received from Mr. W. D. Ware of Ystradgynlais, Swansea, several fossils which clearly belonged to undescribed species of the rare and problematical genera *Vetacapsula* and *Palaeoxyris*. In the course of preparing descriptions of these specimens it became evident that the definition of certain existing species of the genera was not entirely satisfactory, and that certain features (e.g. the angle formed by the ribs in *Palaeoxyris*) have never received accurate description. A careful comparison of all available specimens [1] also brought to light a much greater variation in the members of individual species than has previously been described. The observations made having necessitated a re-statement of the diagnostic characters, a brief critical revision of the two genera has been undertaken. Previous records of the fossils have been classified and a number of new records made. The present account is concerned with morphological considerations only, but it is hoped, at a later date, to deal with the nature and affinities of the organisms.

GENERAL DESCRIPTION

Vetacapsula and *Palaeoxyris* are fusiform sacs of varying proportions and dimensions. While certain authors [2] have regarded the fossils as composed of a number of leaf-like valves united by their margins, Pruvost [3] and others consider them to consist of two valves only, each bearing several longitudinal ribs. Nathorst,[4] however, suggested (for *Spirangium*=*Palaeoxyris*) a construction built up of tubes, after the manner of the 'fruits' (oogonia) of *Chara*. I postpone, at this stage, a discussion of the two latter

[1] The specimens examined include those in the following collections: The Museum of Practical Geology and Geological Survey Collections, London; Geological Survey (Scottish Office); British Museum (Natural History); Manchester Museum; Bristol Museum; Barnsley Naturalist and Scientific Society; Geological Survey of Sweden; the Riksmuseets Paleobotaniska Avdelning, Stockholm. Specimens have also been examined in the private collections of Mr. H. W. Hughes of Dudley and Mr. W. R. Barker of Barnsley, while a number of workers have sent me examples which they had collected. My thanks are due to the curators and owners of the various collections for kind assistance in this matter.

[2] See Kidston, R., 1886, 'On the Species of the Genus *Palaeoxyris*, Brongniart, occurring in British Carboniferous Rocks,' *Proc. Roy. Phys. Soc. Edinb.*, vol. ix, p. 59.

[3] Pruvost, P., 1919, 'La faune continentale du terrain houiller du nord de la France,' *Mém. Carte Géol. Dét. de la France*, pp. 445-446.

[4] Nathorst, A. G., 'Om *Spirangium* och dess förekomst', I, Skånes Kolförande Bildningar, Sveriges Geol. Undersökning, Ser. C, No. 36, 1879, pp. 1-13, pl. vi, vii. (I am most obliged to Dr. R. Florin, of the Riksmuseets, Paleobotaniska Avdelning, Stockholm, for kindly providing me with a resumé of Nathorst's paper.)

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views, Pruvost's conception being sufficient for descriptive purposes. The ribs borne on the valves are more or less raised, and vary in number in different species, the areas between them being termed 'bands' or 'segments.'[1] In *Palaeoxyris* the valves are twisted longitudinally, so that the ribs appear as spiral lines traversing them at various angles, and, in examples which have suffered compression during fossilisation, by their intersection, dividing the segments into rhomboidal areas. These rhomboids were originally described by Brongniart [2] as representing adpressed imbricating scales, but were subsequently shown by Schimper [3] to be merely due to compression of the organism in fossilisation. In *Vetacapsula*, on the other hand, the valves typically remain erect and the ribs pursue a longitudinal course roughly parallel to the longer axis or, more correctly, to the contour of the fossil. Apparent exceptions to this construction are seen in *Vetacapsula johnsoni* (Kidston) and *V. czernyshevi* Chabacov[4], where locally a slight spiral twist is observable in the ribbing.

In *Vetacapsula* and *Palaeoxyris* the body tapers at one extremity into a 'beak' and at the other into a 'pedicle,' the former, when preserved intact, having a definite sharply pointed termination, but the latter appearing to have been of indefinite length. At or just below the centre of the fossil is an enlarged, deformed, or crumpled region which is so constantly present in the organisms as to undoubtedly represent the original site of an essential organic structure.

The Significance of Surface Markings

(*a.*) Direction

In 1886 Kidston [5] noted the presence of 'very fine oblique lines' on the segments of a specimen of *P. prendeli* from Coseley, and an example of that species (No. V.1173) preserved in the British Museum bears similar oblique lines.

On the other hand, fine lines parallel to the ribbing may be observed on the beak of a specimen of *P. prendeli* (No. L.8672) preserved in the Manchester Museum. In 1870 the latter type of marking had been noted by Lesquereux [6] as occurring on a specimen of *P. helicteroides*, and, in 1911 Mr. J. W. Jackson [7] called attention to specimens of *P. helicteroides* from Lancashire, some of the bands of which exhibited, both on the body and on the beak, a striation parallel to the ribbing: this he thought

[1] It should be noted that the terms 'valves', 'ribs', 'bands' and 'segments' have often been very loosely used by certain authors.

[2] Brongniart, A., 1828, 'Essai d'une flore du grès bigarré,' *Ann. des Sci. nat., Ie Ser.*, vol. xv, p. 456.

[3] Schimper, W. Ph., 1869-1874, 'Traité d. paléont. végét.', vol. ii, p. 515.

[4] Chabacov, A. W., 1927, 'Sur une découverte des oeufs d'élasmobranches *Palaeoxyris* et *Vetacapsula* dans les dépôts carbonifères de la Russie,' *Bull. du Comité Géol. Léningrad*, vol. xlvi, No. 1, pp. 33-34, text-fig. 3, p. 33.

[5] Kidston, 1886, *op. cit.*, pl. I, f. 5 a, pp. 62-63.

[6] Lesquereux, L., 1870, *Geol. Surv. of Illinois*, vol. iv, pp. 464-465, pl. xxvii, f. 10, 10b (as *P. prendeli*).

[7] Jackson, J. W., 1911, 'Remarks on some *Palaeoxyris* from the Middle Coal Measures of Lancashire,' *Lancashire Naturalist* (Jan., 1911), p. 328.

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'to represent the actual impression of the outer surface of the organism,' comparing it with the condition found on the egg-capsules of the Port Jackson Shark and other fish. I have examined all available specimens of *P. helicteroides* and the presence of such ornamentation is not uncommon. The collection of the British Museum contains three specimens so marked, while that of the Museum of Practical Geology includes no less than 18. Although the occurrence of similar lines in the genus *Vetacapsula* has not hitherto been recorded, they are found in a few instances, e.g., on one or two examples of *V. cooperi*. Striae running parallel to the ribbing have been noted in two species of *Fayolia*, namely, *Fayolia sterzeliana*[1] and *F. crenulata*[2], while a specimen of *Fayolia sp.*[3] (No. R.C.253, Museum of Practical Geology), collected by Mr. Ware from the Ystradgynlais Colliery, South Wales, bears such markings on portions of the bands. In this genus also they have been compared with the fine lines on the egg-cases of the Port Jackson Shark[4].

In determining the significance of these markings on various specimens of *Palaeoxyris*, it should be remembered that in *P. helicteroides*, as in the much rarer *P. prendeli*, they may take various directions, although that parallel to the ribs is the most frequently found.

Very occasionally, in compressed specimens, the segments bear striae running parallel to each of the two intersecting systems of ribs[5], and tending to form minute faintly-marked rhomboids within the normal rhomboids. A fragment of *Palaeoxyris sp.*, sent me by Mr. J. Walton, and collected from above the Arley Mine (Yorkian Series) at Poynton Colliery, Cheshire, bears crossed striae of this kind, while two or three similar examples (on *P. helicteroides*) may be seen in the Museum of Practical Geology.[6]

Two specimens in the British Museum and ten in the Museum of Practical Geology show transverse striae ; in some cases these are so fine as to be discernible only with the aid of a lens, but in others they are clearly visible to the naked eye. One such specimen is figured on Pl. II, fig. 9.

(*b.*) Distribution

Only in very rare instances are the striae distributed over the whole fossil, although the specimen may appear to be equally well preserved throughout. They are usually confined to a few segments only, and the rest of the fossil may be smooth,

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[1] Weiss, C. E., 1887, 'Ueber *Fayolia sterzeliana* n. sp.,' *Jahrb.d.k.preuss.geol.Landesanst.*, p. 94, pl. iv.

[2] Moysey, L., 1910, 'On *Palaeoxyris* and other Allied Fossils from the Derbyshire and Nottinghamshire Coalfield,' *Quart. Journ. Geol. Soc.*, vol. lxvi, p. 339.

[3] This specimen will be described later.

[4] Renault, B., and R. Zeiller, 1888, 'Sur l'attribution des genres *Fayolia* et *Palaeoxyris*,' *Compt. rend.*, vol. cvii, pp. 1022-1025.

[5] This phrase is, of course, purely descriptive ; 'the two intersecting systems of ribs' as is pointed out above, are due to compression of the fusiform body which bore spiral ribbing.

[6] E.g. specimen J.P. 1009, from the Swansea Four-foot Seam at Cae-newydd Colliery, near Gowerton Station, South Wales. The feature is well-marked in this specimen.

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but in many cases there is a parallel striation on the beak and a transverse on certain segments of the body, while occasionally the reverse arrangement is found. Again, as in the example figured on Pl. II, fig. 9, transverse lines may be superimposed on parallel, each type nevertheless predominating on different parts of the organism; in this case the former are found on the beak and upper part of the body, and the latter on the lower half. It should also be noted that many otherwise excellently preserved specimens are quite devoid of markings of any kind. In view of these facts there can be little doubt that *the various types of ornamentation described do not represent original features in the specimens, but have been formed in the processes of mineralisation.*

Relationship between the Genera

First impressions suggest, and especially in considering the local spiral arrangement of the ribbing occasionally found in *V. johnsoni* and in the single known specimen of *V. czernyshevi*, that there is little or no real distinction between these two genera—that in *Vetacapsula* the ribs have not attained a definite spiral course through lack of maturity or some such accidental cause. The presence or absence of spiral ribbing, however, is by no means their only distinguishing character, and, though certain features are not constant, the two genera may be contrasted as in the following table:

	Vetacapsula	*Palaeoxyris*
Shape	usually broadly fusiform	more narrowly fusiform
Ribbing on body	not spiral, or only slightly (and locally) spiral	definitely spiral
Ribbing on pedicle	straight, and parallel to longer axis	twisted in spirals
No. of ribs	large	small
Width of segments	narrow	wide
Median ridge	present in most species	absent
Longitudinal symmetry	tendency to non-symmetry where central ridge is weak or absent	symmetrical

The distribution of the genera, both in time and space, is also significant. While *Palaeoxyris* is known not only from Britain and various continental countries, but also from North America, *Vetacapsula* has been recorded from Britain only, with the exception of the single record from the Russian Carboniferous. Again, while *Palaeoxyris* is recorded at a number of horizons, e.g., the Coal Measures, Trias, Rhaetic, Lower Lias and Wealden, *Vetacapsula*,

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so far as is known, is confined to the Coal Measures. *The two genera must thus be regarded as distinct, though they are obviously closely allied.*

SPECIES OF *VETACAPSULA*

Vetacapsula cooperi Mackie

Pl. I, figs. 1, 4.

The type specimen of *V. cooperi* is preserved in the British Museum (No. V.5419), and is here re-figured in Pl. I, fig. 1. Mackie's[1] brief description of the fossil is unsatisfactory, and his probable intention to amplify it in conjunction with Mr. C. W. Crocker never having materialised, Crocker cannot be cited as joint author of the species. In a later note, Mackie[2] indicated that the horizon and locality of his fossil were unknown.

The pedicle, of which 4 cm. are preserved, expands fairly gradually, without the formation of a definite 'shoulder', into a more or less ovate body. The latter is about 4.2 cm. in length and tapers into a beak of which only 1.6 cm. is preserved. At its widest point, just below the middle of the body, the fossil measures 3.9 cm., and it is here that the distorted area occurs. Running down both beak and body is a strong central ridge, but this is scarcely observable in the pedicle. As the result of the careful development of an apparently deformed specimen, Moysey[3] concluded that this ridge was due to the original presence of a flange which, on splitting the nodule containing the specimen, was torn off and left embedded in the matrix of the counterpart. There are about 25 longitudinal ribs across the widest part of the body, arranged fairly symmetrically on either side of the stronger median ridge. The ribs show no tendency to pursue a spiral course in any part of the fossil. The specimen is practically symmetrical in the longitudinal direction about the strong central line.

Vetacapsula cooperi is very variable in size, the average length and breadth being 3 cm. and 2.5 cm. respectively, but an example collected by Moysey and now in the Museum of Practical Geology (No. 47923) measures 4.8 cm. by 4.3 cm. (Pl. I, fig. 4), while an even larger, though less complete, specimen is exhibited in the British Museum (No. V.1395). The former example is in an excellent state of preservation, and the central ridge is clearly seen in beak, body and pedicle. The pedicle is 4 cm. long and 1 cm. broad, but the beak is incomplete, being perfectly preserved, however, in the counterpart (No. 47922) where it is seen to be 4 cm. long and sharply pointed. The ribs at the widest part of the body are about 1.5 mm. apart, showing no spiral arrangement at any point. In 1911, Mr. J. W. Jackson[4] described and figured a single specimen (No. L.9581, Manchester Museum), of this species from an unknown

[1] Mackie, J., 1867, 'Undescribed Vegetable Fossil,' *Geol. and Nat. Hist. Repertory*, vol. i, 1865-1867, pp. 79-80, text-fig. 12.

[2] *Op. cit.*, p. 216.

[3] Moysey, L., 1913, 'Some Further Notes on *Palaeoxyris* and other allied Fossils, with Special Reference to some New Features found in *Vetacapsula*,' *Rep. Brit. Assoc. Adv. Sci.*, 1913 (Birmingham), p. 492.

[4] Jackson, J. W., 1911, *op. cit.*, p. 330, pl. xi, f. i.

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locality. It is a typical example, but, by some curious mischance most, but not all, of the measurements given in the description are approximately doubled, as will be seen by referring to the figure (which is slightly less than natural size). I have examined this specimen, and the description should read, " At a distance of 4 cm., the pedicle, which is here about 12 mm. wide, expands into a globular body some 3.7 cm. in length and 3 cm. in breadth. The body then narrows to form a beak of 2.4 cm., or more, in length. The actual termination of the beak is not present owing to a breakage at this point."

Revised diagnosis of *Vetacapsula cooperi* Mackie

Body broadly fusiform, practically longitudinally symmetrical; usually longer than broad; from 2.5 to 4.9 cm. long and 2.5 to 4.6 cm. broad. Pedicle expands into body gradually, without forming a 'shoulder'. From 17 to 25 longitudinal ribs, 1.1 to 2.5 mm. apart, traverse the fossil, exhibiting no spiral tendency: there is a strong median ridge.

DISTRIBUTION

Horizon: ? Coal Measures.
Locality: unknown (C. W. Crocker—Mackie's type specimen).

Horizon: New Mine or White Ironstone (Yorkian Series).
Locality: near Dudley, Staffordshire (J. P. Capewell).

Horizon: Thick Coal (Yorkian Series).
Locality: Chilvers Coton Claypit, Warwickshire (R. D. Vernon).

Horizon: Furnace Coal (Yorkian Series).
Locality: Cossall Claypit, Nottinghamshire.

Horizon: Silkstone Coal (Yorkian Series).
Locality: Callow Colliery, Chesterfield (J. W. Jackson).

Horizon: between the Deep Hard and the Silkstone Coals (Yorkian Series).
Locality: Bonds Main Colliery, Temple Normanton, Derbyshire (L. Moysey).

Horizon: Arley Mine Coal (Yorkian Series).
Locality: Sparth Bottoms, Rochdale, Lancashire (W. H. Sutcliffe).

Vetacapsula moyseyi n.sp.

Pl. I, fig. 6.

In 1913, Moysey[1] observed that *Vetacapsula cooperi*, as described by him in 1910,[2] included two distinct species, and suggested that Mackie's type be designated 'forma β', and the divergent type 'forma α', but did not distinguish between them beyond indicating their characteristic shapes. I here remove Moysey's *V. cooperi* forma α from Mackie's species and redescribe it as *V. moyseyi* n.sp. The specimen figured on Pl. I, fig. 6 was collected by Moysey from the Kilburn Coal (Lanarkian Series[3]) at Loscoe Colliery, Derbyshire, and is now in the Museum of Practical Geology (No. 47925).

[1] Moysey, L., 1913, *op. cit.*, p. 492.
[2] ——, 1910, *op. cit.*, p. 335.
[3] 'Concealed Coalfield of Yorkshire and Nottinghamshire' (*Mem. Geol. Surv.*), 2nd ed., 1926, p. 10.

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The total length of the fossil is 5.6 cm. The margins of the pedicle, which measures 2.5 cm. long and 5.5 mm. broad, take a strong curve in passing into the body, a feature well described by Moysey.[1] 'The pedicle expands suddenly into the body, thus forming a characteristic rounded shoulder in the contour of the body at its lower third, and imparting to the body, in its present compressed state, a shape somewhat like that of a conventional heart inverted.' In *V. moyseyi* the body of the fossil is broader than long, this specimen measuring 2.7 cm. in width and 2.2 cm. in length, and the region of greatest width being situated farther down the body than in *V. cooperi*. The margins which converge to form the beak are also noticeably less curved than in that species. About 16 ribs occupy the broadest portion of the body, each adjacent pair being separated by 2 mm. Body and beak are practically symmetrical about a strong median longitudinal ridge, the pedicle, however, taking a slightly oblique course. The beak is incomplete, but it probably terminated in a point.

As in *V. cooperi*, the specimens vary considerably in size. Moysey described his specimen (from Newthorpe Claypit, Eastwood), as 5.6 cm. broad by 4.7 cm. long, while in the Kidston Collection (No. 6994) is the plaster cast of a specimen from Coalbrookdale the body of which measures 5.6 cm. broad by 4.5 cm. long.

Diagnosis of *Vetacapsula moyseyi* n.sp.

Body broader than long: from 2.2 to 4.7 cm. long by 2.7 to 5.6 cm. broad, shape of a conventional heart inverted. Transition from pedicle to body comparatively sudden. Ribs shew no spiral tendency and at the widest point, towards the base of the body, are separated by 2 to 3 mm. There is a strong median ridge and the fossil is practically longitudinally symmetrical (except for the pedicle).

DISTRIBUTION

Horizon: well below the Top Hard Coal (Upper Beds of Yorkian Series).
Locality: Newthorpe Claypit, near Eastwood, Nottinghamshire (L. Moysey).

Horizon: Yorkian Series.
Locality: Coalbrookdale.

Horizon: Kilburn Coal (Lanarkian Series).
Locality: Loscoe Colliery, Derbyshire (L. Moysey).

Vetacapsula johnsoni (Kidston)

Pl. I, figs. 2, 3, 5.

Kidston's species—which he placed in the genus *Palaeoxyris*—

[1] Moysey, L., 1910, *loc. cit.*

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was based on the only specimen he had then seen. It came from Coseley, and is now in the British Museum (No. V. 1173a), while the Kidston Collection contains a plaster-cast of the fossil (No. 191). Kidston's [1] drawing of his fossil is scarcely satisfactory, and it is re-figured on Pl. 1, fig. 2. Owing to the absence of a marked spiral arrangement of the ribs, Moysey[2] suggested that the species should be referred to the genus *Vetacapsula*, and I adopt his suggestion on this and the following additional grounds:

(1) The body is more broadly fusiform than is usual in examples of *Palaeoxyris*.
(2) In the pedicle the ribs are parallel to the longer axis.
(3) There is a comparatively large number of ribs traversing the body, and the segments between them are consequently narrow.
(4) A median longitudinal ridge is present.

A careful examination of the type specimen suggests that the spiral tendency of the ribs has been accentuated, if not entirely caused, by lateral compression during fossilisation, the median ridge clearly having been displaced to one side. In those portions of the body which are crushed, the intersection of the ribs produces the effect of rhomboidal areas measuring about 1 mm. long and .8 mm. wide. The total length of the specimen is 4.8 cm., this being made up of an imperfect pedicle, a body 3.2 cm. long, and an incomplete beak of about 5 mm. Rather more than half-way down the body is situated the widest part, measuring 14 mm., and corresponding in position with the distorted area. The ribs are .5 mm. or a little less apart.

A clearer, and uncompressed, example of the species, now in the Kidston Collection (No. 908), is figured on Pl. 1, fig. 5. In this specimen also, the slight twist in the course of the ribs is probably, at least in part, accidental. The median ridge is less prominent than in the last specimen. Of four good specimens of *V. johnsoni* from Coseley, now preserved in the British Museum, the best is that figured on Pl. 1, fig. 3. The ribs on the body have a slight spiral tendency and are separated by about .5 mm. A median longitudinal ridge is present: though not well marked in this specimen, in the other three examples (Nos. V. 12600, 12601, 1173b) it constitutes a prominent feature.

Revised diagnosis of *Vetacapsula johnsoni* (Kidston)

Body broadly fusiform, from 2.2 to 4.5 cm. long and from 14 to 21 mm. broad at widest point (just below midway); average length 3.3 cm., average width 1.8 cm.; ribs numerous and closely placed (about

[1] Kidston, R., 1886, *op. cit.*, pl. I, f. 6, p. 63.
[2] Moysey, L., 1910, *op. cit.*, p. 334.

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.5 mm. apart), sometimes with a slight local tendency to a spiral arrangement; ribs in pedicle parallel. There is a more or less strong central ridge.

DISTRIBUTION

Horizon : ? Yorkian Series.
Locality : Worsborough Openworks, near Barnsley, Yorkshire (L. Moysey).

Horizon : Barnsley Thick Coal (Yorkian Series).
Locality : Barnsley, Yorkshire (L. Moysey).

Horizon : Yorkian Series.
Locality : Coseley, near Dudley, Staffordshire (H. Johnson and L. Moysey).

Horizon : above Thick Coal (Yorkian Series.)
Locality : near Bilston, South Staffordshire (C. Holcroft).

Horizon : Dunsil Coal (Yorkian Series).
Locality : Tibshelf Colliery Claypit, Derbyshire (L. Moysey).

Horizon : below Top Hard Coal (Yorkian Series).
Locality : Shipley Manor Claypit, near Ilkeston, Derbyshire (L. Moysey).

Horizon : Top Hard Coal (Yorkian Series).
Locality : Digby Claypit, Kimberley, Nottinghamshire (L. Moysey).

Horizon : Four-Foot Rider Seam (Yorkian Series).
Locality : Nantgwyn Colliery, Penygraig, Rhondda, Glamorgan (D. Davies).

Vetacapsula kidstoni n. sp.

Pl. I, figs. 7, 8.

Four specimens collected by Mr. Ware are referred to this species. They occur in shale and are as follows :

No. R. C. 245 (and counterpart R. C. 246).
Horizon : Rhyd Vein (Yorkian Series).
Locality : Upper Cwm-Tawe Colliery, Abercrave, South Wales.

No. R. C. 248 (bearing two specimens) and No. R. C. 247.
Horizon : Brass Vein (Yorkian Series).
Locality : Diamond Slant, Ystradgynlais, near Swansea.

Associated with R.C. 245 are twigs of *Lepidodendron lycopodioides* Sternb. and fragments of shells which are identified by Mr. J. Pringle as those of fresh-water lamellibranchs. The total length of the fusiform specimens varies from 1.8 to 2.8 cm., while they are from 5 to 6 mm. wide. The pedicle and beak merge so gradually into the body that it is difficult to determine their exact limits, but in the fairly complete specimen (R.C. 248) the total length of 2.8 cm. is made up of, pedicle (about) 9 mm., body (about) 14 mm., and beak (about) 5 mm. Both beak and pedicle take a slightly oblique course. There is practically no tendency towards the spiral arrangement of the ribs. The beak is incomplete in all four specimens. Across the widest part of the body (that is, slightly below its centre) are from 8 to 12 ribs, about .5 mm. apart. A central ridge is absent from these specimens and the body is non-symmetrical in the longitudinal direction. In this connection it is interesting to note that most specimens of *Vetacapsula* show a fair degree of correspondence

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between the strength of the central ridge and the approach to longitudinal symmetry, while in *Palaeoxyris* the fossil is longitudinally symmetrical in the absence of a median ridge. In *V. kidstoni* there is the usual distorted region below the centre of the body, and this area has a granular appearance in specimen R.C. 247. The latter example also bears, below the commencement of the beak, a rounded protuberance similar to those described by Moysey[1] as occurring on *Palaeoxyris helicteroides*, and regarded by him as indicating infection by parasitic organisms.

V. kidstoni stands near to *V. minima* Moysey[2] (collected from above the Fiddler's Vein (Yorkian Series) at Bridge Patch, between Wiseman's Bridge and Amroth) but the ribs are about twice as wide apart, while there is no median longitudinal ridge. Moysey described a marked central ridge in his specimen and thought[3] ' the fossil was not truly cylindrical, but that it had two, or possibly four, angles in the contour of its transverse section.' He compared *V. minima* with a specimen collected by Mr. W. Hemingway from below the Haigh Moor Coal (Yorkian Series) at Brightside, Sheffield, in which the ribs were about 1 mm. apart[4]. Both *V. minima* and *V. kidstoni* are separable from *V. johnsoni* in point of size and in the number of ribs present.

A small, uncrushed form, somewhat similar to *V.kidstoni*, was figured in 1927 by Chabacov[5] from the Carboniferous of Russia, under the name *V. czernyshevi*, this being the first record of the genus from outside Great Britain. From Chabacov's line drawing, it is evident that the fossil is .6 cm. wide at the broadest point, while the body measures 1.8 cm. in length ; there are 10 ribs about .6 mm. apart. The latter are slightly spiral (as in *V. johnsoni*), and the body is non-symmetrical in the longitudinal direction. There is no sign of a central ridge. While the pedicle is well represented (bearing parallel ribs), the beak is not preserved. This specimen differs from *V. kidstoni* in size and in the spiral twist given to the ribs.

Diagnosis of *Vetacapsula kidstoni* n.sp.

Body fusiform, not symmetrical, about 1.4 cm. long and 5 to 6 mm. wide, very gradually tapering above into the beak and below into the pedicle. The widest part of the body has 8-12 ribs which are about .5 mm. apart ; they follow the contour of the body and are not in spirals. There is no median longitudinal ridge.

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[1] Moysey, L., 1910, *op. cit.*, p. 334.

[2] Moysey, L., 1913, in Goode, R. H., ' On the Fossil Flora of the Pembrokeshire Portion of the South Wales Coalfield, ' *Quart. Journ. Geol. Soc.*, vol. lxix, pp. 266, 267, pl. xxx, f. 3. It has not been possible to examine this specimen.

[3] *Loc. cit.*

[4] Moysey (*loc. cit.*) observed that this specimen was in the Kidston Collection, but it is not now there, and I have not been able to trace it.

[5] Chabacov, A. W., 1927, *loc. cit.*

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BRITISH SPECIES OF *VETACAPSULA*

(The chief diagnostic features are marked by an asterisk).

	V.cooperi Mackie	*V.moyseyi* n. sp.	*V.johnsoni* (Kidston)	*V.kidstoni* n. sp.	*V.minima* Moysey
Shape of body	* broadly fusiform ; longer than broad	* conventional heart inverted ; broader than long	broadly fusiform	fusiform	fusiform
Expansion of pedicle	* fairly gradual, forming no ' shoulder '	* sudden, forming a ' shoulder '	* fairly gradual	* very gradual	very gradual
Breadth of body	2.5-4.6 cm. (av. 3 cm.)	2.7-5.6 cm.	* 1.4-2.1 cm. (av. 1.8 cm.)	* .5-.6 cm.	.5 cm.
Length of body	2.5-4.9 cm. (av. 3.5 cm.)	2.2-4.7 cm.	* 2.2-4.5 cm. (av. 3.3 cm.)	* 1.4 cm.	1 cm.
Longitudinal symmetry of body	symmetrical	symmetrical	variable	* non-symmetrical	* symmetrical
Number of ribs	17-25	16-26	* 35-60	* 8-12	20
Distance between adjacent ribs	1.1-2.5 mm.	2-3 mm.	* .4-.6 mm.	* .5 mm.	* .25 mm.
Course of ribs	not spiral	not spiral	sometimes slightly spiral	not spiral	not spiral
Median ridge	present, strong	present, strong	present, varies in strength	* absent	* present, strong
Figured	pl.1,figs. 1, 4.	pl. 1, fig. 6.	pl.1,figs. 2, 3, 5.	pl 1, figs. 7,8.	Q.J.G.S., lxix pl. xxx, fig. 3.

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Species of *Palaeoxyris*

Palaeoxyris helicteroides (Morris)

Pl. II, figs. 4, 9.

In 1840 Morris[1] gave a short description of this the commonest British species of *Palaeoxyris* under the name *Carpolites helicteroides*, believing it to be a fruit. Kidston[2] somewhat amplified Morris' account in 1886, but Moysey's[3] description of 1910 requires little comment. One of the two syntypes is re-figured on Pl. II, fig. 4.

The fossils are composed of 8 segments, 4 narrow alternating with 4 broad bands, a construction which separates this from all other known species of the genus (in which the segments are all of approximately equal breadth). The angle at which the ribs arise varies between 45 and 60 degrees. The pedicle is invariably traversed by spirally arranged ribs, but those in the beak are roughly parallel to its longer axis, converging towards the pointed apex. In recording an incomplete specimen of *P. helicteroides* from the Bristol Coalfield, Dr. H. Bolton[4] observed that the ribs were spirally arranged in the beak, but a re-examination of the fossil (Bristol Museum, No. C. 973) leaves no doubt that the part referred to is the pedicle, and Dr. Bolton has written expressing agreement with this. Though it is usually straight, the pedicle is not infrequently curved. In perfectly preserved specimens, which are rare, the beak is almost as long as the body (about 2.5 cm., e.g., in Nos. Za 2578, 2637, Museum of Practical Geology), and, as Moysey observed, ' It has a slight twist on itself, like that on the blade of a ship's propeller '. Thus, while in transverse section the body was roughly circular, the beak was a flattened organ. The deformed area occurs just below the centre of the body. While the body of average specimens measures about 3.2 cm. in length and 1.2 cm. in breadth, the length may be as small as 2.6 cm. or as large as 6 cm., and the width varies from .7 to 3 cm.

Distribution

Previous records.

Horizon : Swansea Four-foot Seam (Radstockian Series).
Locality : Tip at Cae-newydd Colliery, about 1 mile N. of E. of Gowerton Station, South Wales. (J. Pringle).

Horizon : 279 feet below Bedminster Great Vein (Staffordian Series).
Locality : South Liberty Colliery, Bedminster, Bristol (H. Bolton—Collection of Bristol Musuem).

Horizon : Yorkian Series.
Locality : Coalbrookdale, Shropshire (Morris' syntypes).

Horizon : Yorkian Series.
Locality : Madeley Court, Shropshire (R. Kidston).

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[1] Morris, J., 1840, in Prestwich, J., ' On the Geology of Coalbrookdale, ' *Trans. Geol. Soc. Lond.*, 2nd Ser., vol. v, Expl. to f. 12, 12 a, pl. xxxviii.
[2] Kidston, R., 1886, *op. cit.*, p. 60.
[3] Moysey, L., 1910, *op. cit.*, p. 331.
[4] Bolton, H., 1911, ' Faunal horizons in the Bristol Coalfield, ' *Quart. Journ. Geol. Soc.*, vol. lxvii, p. 316 ,pl. xxvii, f. 20, 21.

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Horizon : Top Hard Coal (Yorkian Series).
Localities : Shipley Manor Claypit, near Ilkeston, Derbyshire (L. Moysey—Kidston Collection, No. 4152; Digby Claypit, Kimberley, Nottinghamshire (L. Moysey—Kidston Collection, No. 4153).

Horizon : Combe Coal, above Top Hard Coal (Yorkian Series).
Locality : Brindsley Claypit, Eastwood, Nottinghamshire (L. Moysey).

Horizon : Waterloo Coal (Yorkian Series).
Locality : Meadow Lane Claypit : Alfreton (L. Moysey).

Horizon : Ten-foot Ironstone Measures (Yorkian Series).
Locality : Clays Croft Openworks, Coseley, Dudley, Staffordshire (H. W. Hughes—Kidston Collection Nos. 6976, 6977, 6979; J. Johnson, No. 6980).
Horizon : Coal Measures (?Yorkian Series).
Locality : Bilston, South Staffordshire.

Horizon : Thick Coal (Yorkian Series).
Locality : Clays Croft Openworks, Coseley, Dudley (H. W. Hughes—Kidston Collection, No. 6981).
Horizon : ?
Locality : Bardsley Colliery, Ashton-under-Lyne, Lancashire (G. Wild—Kidston Collection No. 6978).

Horizon : Fairbottom Mine Coal (of the Bardsley Colliery).
Localities : Hill-pit, Limeside, Bridge Pit, Knott Lane (G. Wild—Collection of Manchester Museum) ; Wood Park ¼ mile west of Bardsley, Lancashire (J. Nield—Collection of Oldham Museum).
Horizon : ?
Locality : Chamber Pits, Fitton Hill, near Oldham (R. Cairns—Collection of Manchester Museum).

Horizon : Barnsley Coal (Yorkian Series).
Locality : Yorkshire.

Additional Records.

Horizon : Barnsley Thick Coal (Yorkian Series).
Localities : Round Green Colliery, Barnsley, Yorkshire (Collection of W. R. Barker of Barnsley) ; Worsborough, near Barnsley (Collection of Barnsley Nat. and Sci. Soc.)

Horizons : 1,896 and 2,174 ft. from surface (Yorkian Series).
Locality : Thom Borehole, Cwmgorse, 3½ miles N.W. of Pontardawe, South Wales (E. Dix and A. E. Trueman).

Horizon : 2,285 ft. from surface (Yorkian Series).
Locality : Trefor Boring, Cwmgorse, South Wales (E. Dix and A. E. Trueman).
Horizon : Brass Vein (Yorkian Series).
Locality : Diamond Slant, Gurnos Anthracite Colliery, Ystradgynlais, Swansea (W. D. Ware).
Horizon : ?
Locality ; Ynyscedwyn Colliery, Ystradgynlais, Swansea (W. D. Ware).

Horizon : Lanarkian Series.
Locality : Woodhill Quarry, Kilmaurs, Ayrshire (D. Landsborough, Kidston Collection No. 593).

Palaeoxyris carbonaria Schimper

Pl. II, fig. 8.

The fusiform body, normally composed of 6 to 8 equally broad segments, varies in length from 2.6 to 3.2 cm., and in width from .8 to 1.2 cm., average specimens measuring 3 cm. long by 1.1 cm. broad. The ribs cross it at an angle of 30 degrees and are separated by about

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2 mm. (occasionally less). Kidston[1] expressed some doubt as to which extremity represented the 'base' (=pedicle) and which the 'apex' (=beak) of one of the specimens he figured. It is clear, however, that the longer extremity, consisting of twisted segments, (and which is marked 'a' in his figure) is the pedicle.

In the British Museum are two specimens from Coseley (Nos. V. 12925, V. 12928) which agree fairly well with this species in most respects, but bearing ribs 1 mm. apart, or even slightly less (and being consequently more numerous than in typical examples of the species). This type may be distinguished as *P. carbonaria* forma α. *P. carbonaria* is very rare in Britain, but White[2] observed that *P. appendiculata* Lesqx.,[3] which was regarded by Kidston[4] and others as synonymous with *P. carbonaria*, appeared to be the commonest American species of the genus. White, however, did not agree with the union of these two species, observing that *P. appendiculata* is distinguished from *P. carbonaria* 'by the narrower valves,[5] and consequently smaller areolation in compressed specimens; and while in *P. appendiculata* the whole organ is, in general, smaller, the dilated portion is proportionally larger'. It should be pointed out, however, that, in describing his type specimen, Lesquereux gave one twelfth of an inch as the average width of the segments, while in *P. carbonaria* they average 2 mm. The two species should, in my opinion, be united.

Distribution

Previous Records.

Horizon: Ten-foot Ironstone Measures (Yorkian Series.)
Locality: Clays Croft Openworks, Coseley, Dudley, Staffordshire (H. W. Hughes and J. Ward—Kidston Collection Nos. 6973, 6974).

Horizon: above Top Hard Coal (Yorkian Series).
Locality: Digby Claypit, Kimberley, Nottinghamshire (L. Moysey).

Horizon: above Barnsley Coal (Yorkian Series).
Locality: Yorkshire.

Horizon.: Lanarkian Series.
Locality: Woodhill Quarry, Kilmaurs, Ayrshire (D. Landsborough—Kidston Collection No. 6975).

Additional Records.

Horizon: 647 feet from surface (Radstockian Series, Keele Beds).
Locality: Claverley Boring, Shropshire (Museum of Practical Geology No. 44691).

Horizon: between Brooch and Thick Coals (Yorkian Series).
Locality: Coseley, near Dudley. (L. Moysey—Bristol Museum, No. Cb. 1566).

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[1] Kidston, R., 1886, *op. cit.*, pp. 61-62, pl. 1, f. 2.
[2] White, D., 1889, 'Fossil Flora of the Lower Coal Measures of Missouri,' *U.S. Geol. Surv.*, vol. xxxvii p. 274.
[3] Lesquereux, L., 1870, *Geol. Surv. Illinois*, vol. iv, p. 464, pl. xxvii, f. 11.
[4] Kidston, R., 1886, *op. cit.*, p. 61, and Moysey, L., 1910, *op. cit.*, p. 330.
[5] The term 'valves', as here used, is equivalent to the term 'segments' as employed in the present and in most recent papers.

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Horizon : Coal Measures.
Locality : Sliddery Water Head, Burn ' B,', south of road (Coll. Geol Surv. Scottish Office, No. 3547).

Horizon : Mynyddislwyn Vein. (Radstockian Series).
Locality : Gelli-deg-level, Maes-y-cwmmer, Monmouthshire (J. Pringle—Museum of Practical Geology, No. J. P. 202).

Horizon : Green Vein (Yorkian Series).
Locality : Trimsaran, Carmarthen (E. Dix and A .E. Trueman).

Palaeoxyris prendeli Lesqx.

Pl. II, fig. 7.

In this very rare species the fusiform body varies in length from 2.5 to 3.4 cm., and in breadth from 1.2 to 1.8 cm. There are from 4 to 8 equal segments 2.5 to 6 mm. wide. The angle at which the ribs arise is usually 45-55 degrees.

DISTRIBUTION

Horizon : Yorkian Series.
Locality : Clays Croft Openworks, Coseley, Dudley, Staffordshire. (H. W. Hughes—Kidston Collection, Nos. 190, 192).

Horizon : Top Hard Coal (Yorkian Series).
Locality : Shipley Claypit, near Ilkeston, Derbyshire (L. Moysey—Kidston Collection No. 4151, and H. S. Holden).

Horizon : well below Top Hard Coal (Yorkian Series).
Locality : Newthorpe Claypit, near Eastwood. Nottinghamshire. (L. Moysey).

Horizon : Combe Coal, above Top Hard Coal (Yorkian Series).
Brindsley Claypit, Eastwood, Nottinghamshire (L. Moysey).

Horizon : Yorkian Series.
Locality : Yorkshire.

Horizon : Arley Mine Coal (Yorkian Series).
Locality : Sparth Bottoms Claypit, Rochdale, Lancashire (L. Moysey and W. A. Parker).

Palaeoxyris trispiralis Kidston

Pl. II, fig. 1.

Kidston's[1] type specimen, with its counterpart, is preserved in the British Museum (Nos. V. 1179 and 6364 respectively), the counterpart being figured on Pl. II, fig. 1. The fossil has a total length of about 12 cm., of which 9 cm. is occupied by the body, 1.7 cm. by the pedicle, and 1.7 cm. by the beak. There are 3 segments, each about 9 mm. across, and the body measures from 3 to 3.4 cm. in width. The small number and great width of the segments are characteristic. By their intersection the ribs, which arise at an angle of 30-40 degrees, divide the segments into rhomboids 16 to 18 mm. broad by 10 to 12 mm. high.

Sutcliffe[2] recorded a specimen, (now in the Manchester Museum,

[1] Kidston, R., 1886, *op. cit.*, pl.I, fig. 7, p. 64.
[2] Sutcliffe, W. H., 1909, 'Notes on *Palaeoxyris prendeli* (Lesquereux), from the Middle Coal Measures, Sparth, Rochdale,' *Lancashire Naturalist*, July, 1909, p.117, text-fig. 3, p. 116.

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No. L. 9128) from the Second Grit Flagstone of Ashworth Moor, near Rochdale, which he referred to this species. Describing it as an uncompressed example, he gave the width as 30 mm., but it is actually partially compressed, and consequently elliptical in transverse section, and, while the greater axis measures (nearly) 30 mm., the smaller, including the raised ribs, is only 20 mm. I have grave doubts as to the attribution of this specimen to Kidston's species; the body appears to be composed of more than the typical 3 segments and the ribs arise at an angle of only 15 degrees. The specimen is smaller and the segments narrower (7 mm.) than in the type specimen.

DISTRIBUTION:

Horizon: Yorkian Series.
Locality: Coseley, near Dudley, Staffordshire (H. Johnson).

Palaeoxyris warei n.sp.

Pl. II, fig. 6.

The fossil (No. R.C. 256) on which this species is based is one of a number collected by Mr. W. D. Ware of Ystradgynlais, Swansea. On the same slab as the specimen are numerous plant-fragments, including *Sphenophyllum cuneifolium* Sternb., *Neuropteris heterophylla* Brongt., *Calamites sp.*, *Asterophyllites charaeformis* (Sternb.), and *Pinnularia capillacea* (L. & H.). In general aspect the specimen resembles *P. trispiralis* Kidston, prominent angles being formed by the meeting of the ribs along its margin. Kidston's species, however, is much larger, the body measuring 9 cm. in length by 3 to 3.4 cm. in breadth, while the present specimen is only 1.8 cm. long by .7 cm. broad. In *P. trispiralis* the ribs arise at an angle of from 30 to 40 degrees, while in *P. warei* the angle is about 30 degrees. Three segments compose the body of the former, while 6 are found in the latter species. The width of the segments is similarly distinctive, being approximately 9 mm. in *P. trispiralis* and 1.5 to 1.8 mm. in *P. warei*. In the latter species also the expansion of the margins in passing from the pedicle to the body is noticeably less rapid. The specimen shows only a small portion of the beak, but the constriction of the neck and the central narrow segment of the beak are clearly seen. About 1 cm. of the pedicle, which was 2 mm. wide, is preserved.

Diagnosis of *Palaeoxyris warei* n.sp.

Body narrowly fusiform, 1.8 cm. long by 7 mm. broad, consisting of 6 equal segments, 1.5-1.8 mm. wide. Ribs arise at an angle of about 30 degrees. Expansion from pedicle to body very gradual.

Horizon: Yorkian Series.
Locality: Gwaunclawdd Colliery, Abercrave, South Wales.

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Palaeoxyris pringlei n.sp.

Pl. II, fig. 2.

This specimen (No. 38557), though well-preserved, is unfortunately not quite complete. It was collected by Dr. L. J. Wills and at the time was provisionally identified by Mr. J. Pringle as a new species of *Palaeoxyris* allied to *P. carbonaria* Schimper. The angle at which the ribs arise is characteristically low, being about 15 degrees. The body is fairly broadly fusiform; it measures 1.8 cm. in length (and, if complete would probably have reached 2.2 cm. or so). Its margins expand fairly rapidly to a maximum breadth of 1 cm. The ribs are from .8 to 1 mm. apart, producing by their intersection small rhomboids which are two or three times as broad as they are high. There are about 14 equally broad segments, as compared with 6 to 8 in *P. carbonaria*. The specimen is somewhat smaller than those of the latter species, the ribs arise at a lower angle, are more closely placed, and more numerous. The beak is complete, measuring about 2 cm. in length, and having a long, almost hair-like point. The pedicle is missing. I have much pleasure in naming this species after Mr. J. Pringle.

Diagnosis of *Palaeoxyris pringlei* n.sp.

Body fairly broadly fusiform, about 2.2 cm. long by 1 cm. broad, composed of about 14 equally broad segments: ribs .8 to 1 mm. apart, arising at an angle of 15 degrees: beak 2 cm. long.

Horizon: Shales below Half-yard Coal of the Coed-yr-allt or Morlas Coals, Coed-yr-allt Series (Newcastle-under-Lyme Group of the Staffordian Series).

Locality: Above the small bridge and about 140 yds. from the Morlas, up the stream flowing from Pentre to Glyn Morlas, near Chirk, N. Wales.

Palaeoxyris edwardsi n.sp.

Pl. II, fig. 3.

Among the specimens collected by Mr. Ware is one (No. R.C. 255) which I name after Mr. W. N. Edwards of the British Museum (Natural History). It measures only 2 cm. in length (though not quite complete) and is the smallest known British species of the genus. The maximum width is 3.5 mm., and the very narrowly fusiform body consists of 5 equally broad segments measuring 1 mm. across. The ribs are more steep than in most species of *Palaeoxyris*, arising at an angle of about 80 degrees, the only British species approaching *P. edwardsi* in this respect being *P. helicteroides*, a fossil with which it could not be confused. The specimen is compressed, and the rhomboids produced by the intersection of the ribs are 4 or 5 mm. high by about 1 mm. wide.

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Diagnosis of *Palaeoxyris edwardsi* n.sp.

Body narrowly fusiform, about 2.2 cm. long by 3.5 mm. wide, composed of 5 equally broad segments 1 mm. broad : angle formed by the ribs 80 degrees, rhomboids much higher than broad.

Horizon : ? Yorkian Series.
Locality : Yniscedwyn Colliery, Ystradgynlais, Swansea.

? Palaeoxyris sp.

Pl. II, fig. 5.

A specimen in shale (No. R.C. 252), collected by Mr. Ware from an unknown horizon at the International Colliery, Abercrave, South Wales, I regard as possibly representing a specimen of *Palaeoxyris* embedded in the vertical position. It is associated with plant-remains and a fragment of a shell which Mr. J. Pringle identifies as that of a fresh-water lamellibranch. The impression is elliptical in shape. The longer axis measures 10 mm. and the shorter 9 mm., and the specimen thus conforms in size with several British Palaeozoic species of *Palaeoxyris*.

A carbonaceous covering at the margin extends inwards for 1 or 2 mm., where it is broken in an irregular manner, revealing a blunt depressed central point from which several slightly curved lines radiate out to the circumference. The central point may represent either the beak or the pedicle extremity in horizontally embedded examples of the genus, while the radiating lines may correspond to the ribs. The specimen is here figured in order to draw attention to this type of fossil.

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BRITISH PALAEOZOIC SPECIES OF *PALAEOXYRIS*.

(The chief diagnostic features are marked by an asterisk)

	P.helicteroides (Morris)	*P.carbonaria* Schimper	*P.prendeli* Lesqx.	*P.trispiralis* Kidston	*P.warei* n.sp.	*P.pringlei* n.sp.	*P.edwardsi* n.sp.
Shape	fusiform	fusiform	fusiform	fusiform	narrowly fusiform	fairly broadly fusiform	very narrowly fusiform*
Length of body	2.6-6 cm. (av. 3.2 cm.)	2.6-3.2 cm. (av. 3 cm.)	2.5-3.4 cm.*	9 cm.*	1.8 cm.*	about 2.2 cm.	2 cm.*
Width of body	.7-3 cm. (av. 1.2 cm.)	.8-1.2 c.m (av. 1.1 cm.)	1.2-1.8 cm.*	3-3.4 cm.*	.7 cm.*	1 cm.	3.5 mm.*
Number of segments	8	6-8	4-8	3*	6*	14	5
Width of segments	alternately broader and narrower; broad, 4-5 mm. narrow, 1-1.5 mm.*	equally broad, 2 mm. (1 mm. in forma α)*	equally broad, 2.5-6 mm.*	equally broad, 9 mm.*	equally broad, 1.5-1.8 mm.*	equally broad, .8-1 mm.	equally broad, 1 mm.*
Angle of ribs	45-60 deg.	30 deg.*	45-55 deg.*	30-40 deg.	30 deg.	15 deg.*	80 deg.*
Expansion from pedicle to body	gradual	gradual	sudden	fairly sudden	very gradual	fairly sudden	very gradual
Rhomboids (in compressed specimens).	of two sizes	as long as broad (about 2 mm.)*	slightly broader than long (5-9 mm. broad 4-6 mm. long)*	broader than long (16 mm. broad, 11 mm. long)	broader than long (3 mm. broad, 2 mm. long)	much broader than long (2.5-3 mm. broad, 1 mm. long)	much longer than broad (1 mm. broad, 4-5 mm. long)
Figured	pl. II, f. 4, 9.	pl. II, f. 8.	pl. II, f. 7.	pl. II, f. 1.	pl. II, f. 6.	pl. II, f. 2.	pl. II, f. 3.

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Explanation of Plate I

Fig. 1.—*Vetacapsula cooperi* Mackie.

Horizon : ? Coal Measures.
Locality : unknown.
Collector : C. W. Crocker.
Collection : British Museum (Natural History) No. V.5149 (Mackie's type specimen). x 1.

Fig. 2.—*Vetacapsula johnsoni* (Kidston).

Horizon : Yorkian Series.
Locality : Coseley, near Dudley, Staffordshire.
Collector : H. Johnson.
Collection : British Museum (Natural History) No. V.1173a (Kidston's type specimen). x 2.

Fig. 3.—*Vetcapsula johnsoni* (Kidston).

Horizon : Yorkian Series.
Locality : Coseley, near Dudley, Staffordshire.
Collection : British Museum (Natural History) No. V. 12929. x 1½.

Fig. 4.—*Vetacapsula cooperi* Mackie.

Horizon : Furnace Coal (Yorkian Series).
Locality : Cossall Claypit, Nottinghamshire.
Collector : L. Moysey.
Collection : Museum of Practical Geology No. 47923. x 1.

Fig. 5.—*Vetacapsula johnsoni* (Kidston).

Horizon : above Thick Coal (Yorkian Series).
Locality : near Bilston, South Staffordshire.
Collector : C. Holcroft.
Collection : Kidston Collection No. 908. x 1.

Fig. 6.—*Vetacapsula moyseyi* n.sp.

Horizon : Kilburn Coal (Lanarkian Series).
Locality : Loscoe Colliery, Derbyshire.
Collector : L. Moysey.
Collection : Museum of Practical Geology No. 47925. x 1.

Fig. 7.—*Vetacapsula kidstoni* n.sp.

Horizon : Rhyd Vein (Yorkian Series).
Locality : Upper Cwm-Tawe Colliery, Abercrave, South Wales.
Collector : W. D. Ware.
Collection : Museum of Practical Geology No. R. C. 245. x 2¾.

Fig. 8.—*Vetacapsula kidstoni* n.sp.

Horizon : Brass Vein (Yorkian Series).
Locality : Diamond Slant, Ystradgynlais, near Swansea.
Collector : W. D. Ware.
Collection : Museum of Practical Geology No. R. C. 248. x 2⅘.

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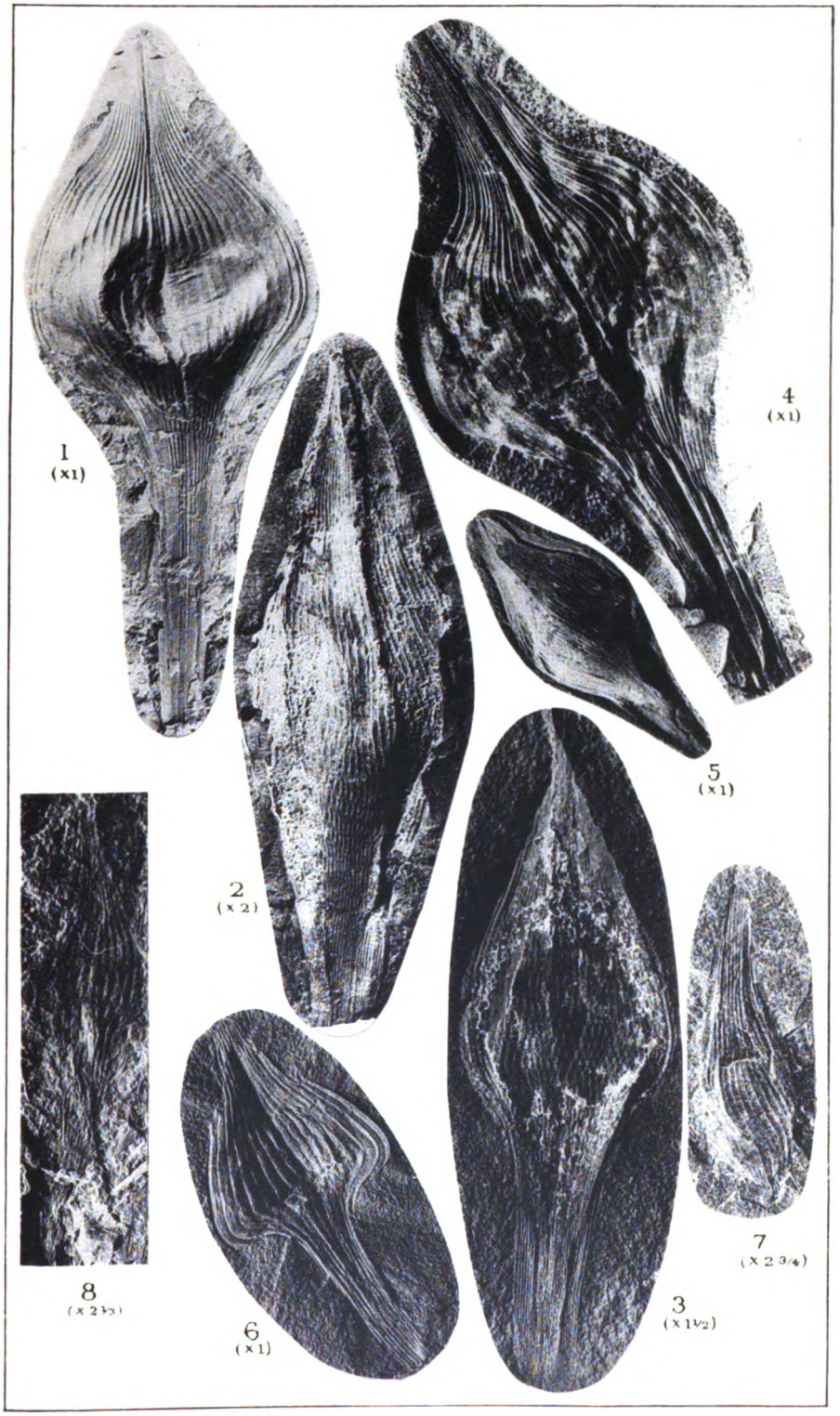

VETACAPSULA.

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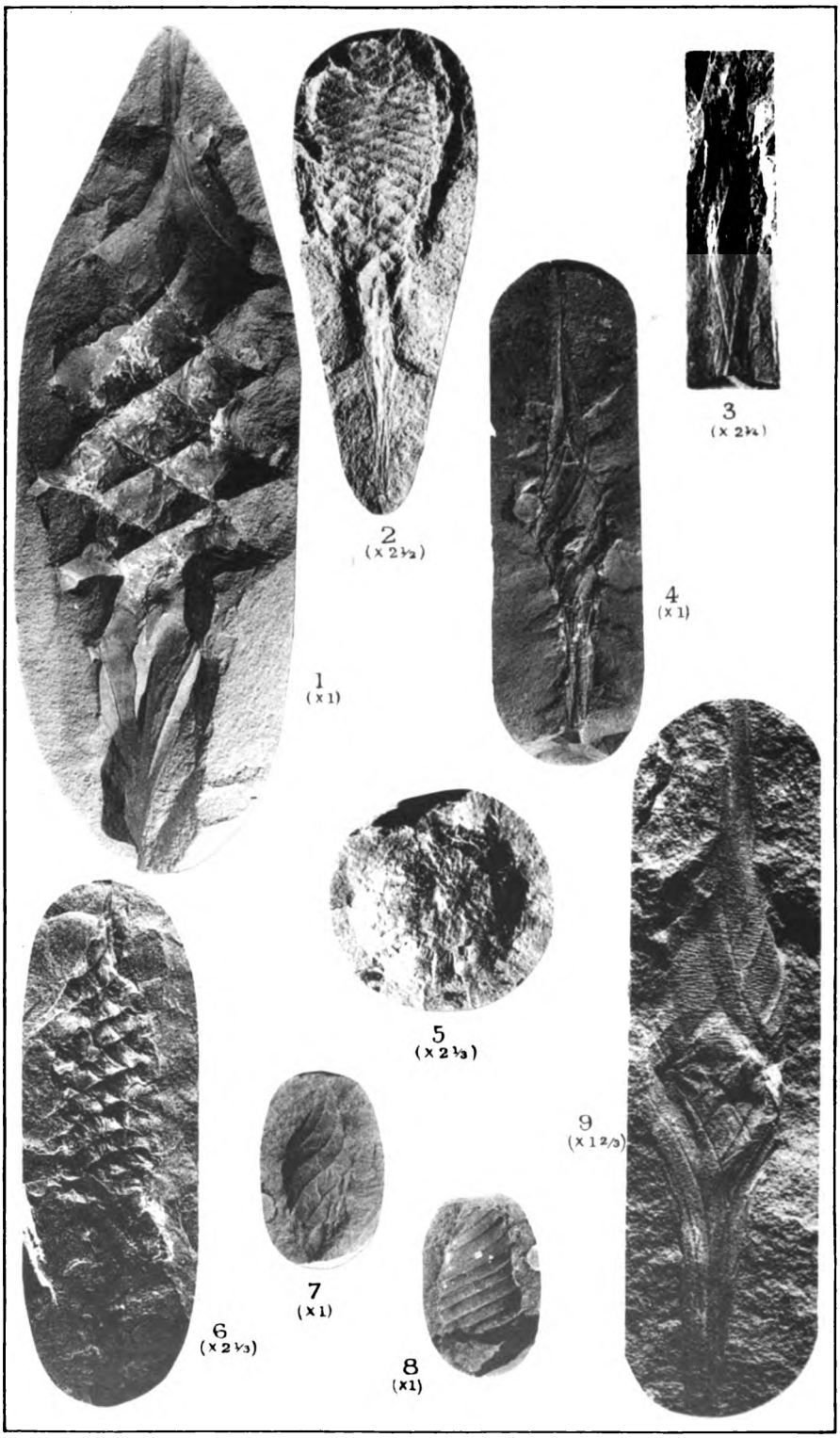

PALAEOXYRIS.

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EXPLANATION OF PLATE II

Fig. 1.—*Palaeoxyris trispiralis* Kidston.
Horizon : Yorkian Series.
Locality : Coseley, near Dudley, Staffordshire.
Collector : H. Johnson.
Collection : British Museum (Natural History) No. V.6343 (counterpart of Kidston's type specimen). x 1.

Fig. 2.—*Palaeoxyris pringlei* n.sp.
Horizon : below Half-yard Coal of the Coed-yr-allt or Morlas Coals, Coed-yr-allt Series (Newcastle-under-Lyme Group of the Staffordian Series).
Locality : above the small bridge and about 140 yds. from the Morlas, up the stream flowing from Pentre to Glyn Morlas, near Chirk, North Wales.
Collector : L. J. Wills.
Collection : Museum of Practical Geology No. 38557. x 2½.
(N.B. The beak of this specimen is pointing downwards on the plate.)

Fig. 3.—*Palaeoxyris edwardsi* n.sp.
Horizon : ? Yorkian Series
Locality : Yniscedwyn Colliery, Ystradgynlais, near Swansea.
Collector : W. D. Ware.
Collection : Museum of Practical Geology No. R.C. 255. x 2½.

Fig. 4.—*Palaeoxyris helicteroides* (Morris).
Horizon : Yorkian Series.
Locality : Coalbrookdale.
Collector : J. Morris.
Collection : British Museum (Natural History) No. V.4259 (one of the two syntypes). x 1.

Fig. 5.— ? *Palaeoxyris* sp.
Horizon : ?
Locality : International Colliery, Abercrave, South Wales.
Collector : W. D. Ware.
Collection : Museum of Practical Geology No. R. C. 252. x 2½.

Fig. 6.—*Palaeoxyris warei* n.sp.
Horizon : ? Yorkian Series
Locality : Gwaunclawdd Colliery, Abercrave, South Wales.
Collector : W. D. Ware.
Collection : Museum of Practical Geology No. R. C. 256. x 2½.

Fig. 7.—*Palaeoxyris prendeli* Lesqx.
Horizon : Yorkian Series.
Locality : Coseley, near Dudley, Staffordshire.
Collector : H. Johnson.
Collection : British Museum (Natural History) No. V.1177. x 1.

Fig. 8.—*Palaeoxyris carbonaria* Schimper.
Horizon : Yorkian Series.
Locality : Coseley, near Dudley, Staffordshire.
Collector : H. Johnson.
Collection : British Museum (Natural History) No. V.1178. x 1.

Fig. 9.—*Palaeoxyris helicteroides* (Morris).
Horizon : Coal Measures (? Yorkian Series).
Locality : Bilston, South Staffordshire.
Collection : British Museum (Natural History) No. V.4260 x 1½.

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REPORT OF THE GEOLOGICAL SURVEY BOARD FOR 1928

TO THE LORDS OF THE COMMITTEE OF THE PRIVY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

MAY IT PLEASE YOUR LORDSHIPS.—

In accordance with our terms of reference, we, the Geological Survey Board, beg to submit our Ninth Annual Report on the work of the Survey and Museum.

Personnel

1. We desire to record our high appreciation of the personnel and organisation of the staff of the Geological Survey and Museum. To this service, in these days, there falls work of great variety and the qualifications of its members are high. Its organisation facilitates an allocation of duties that takes account of the fitness of individuals for particular types of work and makes provision for meeting promptly a call for concentration on one matter or another. The standard for recruitment has been fully maintained throughout the expansion of duties and the increase of establishment that have marked the past ten years.

Accommodation (London)

2. **Headquarters.**—The inadequacy of the accommodation in the Headquarters offices in Jermyn Street causes serious difficulties for every section of the staff—not least for the members of the field staff who have there, in the winter months, to work up the results of their field work with full opportunities of access to collections and records and of consultation with their colleagues. The gradual increase in the volume of the services the Survey provides, and the need for early and adequate records of all information collected, have made crowding inevitable. The congestion that now obtains is a serious handicap on these services and it ought to be relieved as early as possible. From no point of view is the early provision of a new building more urgent than as an essential to the full utilisation of the work of the staff.

Museum.—In Section 34 of their Interim Report the Royal Commission on National Museums and Galleries deal at length with the position of the Museum of Practical Geology. We are glad to note their strong recommendation that a new Museum on lines already discussed and approved by us should be erected at South Kensington. We understand that early action is to be taken on this recommendation.

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In the evidence he submitted to the Royal Commission, the Director of the Geological Survey and Museum gave a clear statement as to the origin, aims and practice of the Museum and as to the nature and extent of the accommodation it requires.

Established as the 'Museum of Practical Geology,' the museum has consistently aimed at illustrating the work of investigators in the Geological Sciences and the relation of the results of such work to current advances in the practice of those who are primarily concerned in forwarding mining, quarrying, metallurgy, communications, sanitation and the many other activities that are concerned with either the deep or the surface deposits of this country. Such illustration is required both for ready exposition of dominant factors in geological conditions and for reference by those who study the detailed information available in the map rooms and libraries of the Survey and Museum in relation to particular scientific and economic interests. Adequate illustration of this kind is indeed essential to the effective publicity of the results of the Survey work.

Further, as it happens, not a few of the most productive advances in the knowledge of geological structure and sequence originated in this country, and the work of the investigators who pointed the way in such new departures is now classic. As the national museum of British Geology, this museum interests all British geologists at home or from overseas; it also attracts every foreign geologist who visits this country. For all such visitors the exposition the Museum provides under this category is a matter of primary value. For effective exposition the first necessity is good exhibition space. In the present building this is gravely deficient; in the new building it will be worthy of the material to be shown, and the examples available will fittingly illustrate the work of the great pioneers with whose names they are associated. In various sections of investigation these names range from that of William Smith—'The father of stratigraphical geology'—at the beginning of the XIXth century, to those of Lapworth, Peach and Horne who in solving, as they did at the end of the century, the complex riddles presented by the schists and gneisses of the North-west Highlands of Scotland, made contributions of the first rank to recent advances in the science.

Accommodation (Scottish and Provincial Offices)

3. The provision for the accommodation of the Scottish Headquarters at Southpark in Edinburgh is excellent except as regards storage space, and we hope that this defect will be made good in the near future.

The branch offices at York, Manchester and Newcastle-on-Tyne are maintained.

Field Work

4. The Director's Report for 1928, which is submitted herewith, shows that the stated programme of field work for the year has been

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carried out and that good progress has been made in the improvement of methods of survey and enquiry, in promoting the ready use of accumulated information of geological value in relation to industries, and in the methods of presenting the results of the work of the Survey.

The Field Units have been engaged on surveys of ten districts as prescribed in the programme approved for the year, viz. :—

Southern District (primary six-inch survey).
Midlands District (primary six-inch survey).
Yorkshire District (revision of six-inch survey).
Lancashire District (revision of six-inch survey).
Cumbrian District (revision of six-inch survey).
Northumberland and Durham District (revision of six-inch survey).
Ayrshire (revision of six-inch survey).
Lanarkshire and Peeblesshire (revision of six-inch survey).
Fife and Kinross (revision of six-inch survey).
Orkney Islands (primary six-inch survey).

Details of the work carried out by each of these Field Units are given in the *Summary of Progress* (pp. 54-83).

Attention was also given to certain sections of the South Wales Coalfield with a view to the revision of the six-inch mapping and the preparation of Vertical Sections embodying the results of recent work. Revised editions of some of the relevant sections are now in the press.

Work involved in the Issue of Maps and Memoirs

5. Alike in respect of the primary six-inch survey work and of the revision of the maps for coalfield and residential areas, we regard the progress as highly satisfactory. The one-inch maps are now issued in well considered colour-printed form and at a low price. These and the new or revised Memoirs on the geology of each area, give publicity to the results of the work of the Survey, and they lead those who are interested on points of detail to the primary six-inch records of which many are published and all are available for reference.

The issue of one-inch maps affords a fair measure of the current activities of the Survey in field work, and from this point of view it is noteworthy that in the past year an exceptionally large number of the English one-inch maps passed through the press.

Each one-inch map issue involves not only careful study by the Field Staff—mapping or revision of earlier mapping, collection of specimens and of records of earlier observations, examination of geological conditions as affecting industry or residence—but also consultation with fellow workers and specialists, and subsequently in the office, detailed description in memoirs and careful preparation for the printer.

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Thus, in the ordinary routine of work the issue of a new or a revised one-inch-to-the-mile map normally marks the completion of a definite area of field work by the field staff engaged on it, and the result of the active co-operation of not a few who may never have seen the area. Equal areas vary greatly in complexity of structure and therefore in the time and study for which they call.

The replacement of the one-inch hand-coloured maps by the less costly colour-printed editions has been progressing steadily. Already, for England and Scotland alike, one third of the 'one-inch' scale sheets are obtainable in the colour-printed form—and these maps are not only cheaper but also, in several respects, better, than the previous hand-coloured maps.

Surveys and Records

6. The primary survey of every area is made on maps to a scale of six inches to a mile, and from these original maps, or from later revisions of them, the universal 1-inch-to-1-mile geological maps are reduced. Copies of the 6-inches-to-1-mile geological maps and many valuable records are held available for reference at the Head-quarters Offices concerned. For the coalfield areas, however, the six-inch maps are also published. In the past year special attention has been given to the revision and issue of these maps. In the case of coalfields which have been extensively developed since the original survey was made, revision work has been heavy—in not a few cases the work was practically that of a new survey. The continuous progress of this work in recent years is gratifying and the detailed record of issues of new or revised maps, which is given in the Report of the Director, shows that publication has already gone far to provide the information required for guidance in the extension of Coal Mining.

The account of 'Inspections of Bores and Shafts' which the Director gives in his Report indicates the extent and value of this work of the Survey, now facilitated by the relevant provisions of the 'Mining Industry Act (1926).'

The accumulation of Records bearing on questions of Water Supply continues steadily. The publication of memoirs dealing with underground water supplies in many areas not only serves these areas directly, but helps to give publicity to the fact that for practically all populous areas much information is available for enquirers at the Offices of the Survey.

Geophysical Work

7. Good progress has been made during the year with the work of testing the Eötvös Gravity Torsion Balance on known areas in Britain. The second test, on a buried channel filled with Drift deposits in the Kelvin valley area, north-west of Glasgow, was

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completed ; a third test in the neighbourhood of Portobello, about three miles east of Edinburgh, was put in hand and the work was practically finished by the end of the year. The object of this latter test was to investigate a well-marked fault or fracture line, bringing together rocks of different ages and differing only moderately in composition and in specific gravity. Full reports on these tests have been published or are in course of publication. As is mentioned in the Director's Report (see p. 35) it can be recorded that the Eötvös Balance has not failed to detect the geological structure which was previously known to exist in the ground examined. Under the circumstances in which the Balance has been employed it has proved to be a scientific instrument capable in skilled hands of yielding results of definite practical value as well as of theoretical interest.

We are glad to find that the experimental work carried out on the uses of the Eötvös Balance proved satisfactory and we trust that such applications of Physical Research may be utilised in geological investigations where the value of the possible results justifies the expenditure of time they involve.

Publication of Memoirs, etc.

8. The output of new memoirs during the year has again been large. Apart, too, from memoirs descriptive of one-inch sheets, other interesting volumes have appeared, viz. : two palaeontological monographs, three new county memoirs on Wells and Springs, and a Classified Catalogue of the Survey's collection of geological photographs and slides. This Catalogue enumerates a wide range of illustrations of geological phenomena and of typical surface features which are of much value for teaching purposes in schools of geology and geography. It is hoped that teachers and lecturers will find this list of considerable assistance to them in their work.

In the production of particular memoirs, as in other sections of its work, the Survey has continued to have the active co-operation of able geologists outside its own ranks, who have dealt with specific investigations in matters of which they have expert knowledge.

Co-operation on Soil Surveys

9. Officers of the Survey have continued to co-operate with experts on the investigation of methods by which the Survey could determine and record characteristics of soil that are of importance in Agriculture and Forestry. The soil map of the Kilmarnock Sheet, to which we referred in our last report, is now with the printer, and it will illustrate a method of recording and presenting information as to the nature of the soil in an extended area of varying soil types. The issue of this map and the accompanying memoir will be of value in enabling those who are interested in the uses of the soil to judge

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as to the service such maps can render. Apart from the preparation of special soil maps, the notes the geological surveyors, after their many consultations with soil experts, are now making upon maps of areas under survey should much increase the value of the work of the Survey to agriculturists.

Method of Reporting

10. During 1928 the *Summary of Progress* of the Geological Survey was for the first time published in two parts. Part I was given to the administrative side of the Survey's work and Part II was entirely devoted to papers on a variety of geological matters arising on the work in hand. It was felt that this arrangement would enable geological students to purchase at a reduced price that part of the Summary which was specially of scientific and of educational value, without having to pay at the same time for the section dealing with administrative matters. By separating Part II from Part I it was found possible to issue the collection of scientific papers at 2s. 6d. per copy, whereas the complete Report for the previous year was priced at 4s. 6d. per copy.

It is believed that this change will be appreciated by geological students and others for whom the cost of such works is a matter of importance.

Programme of Field Work

11. The programme of field-work for 1929 is :—

(*a*) primary mapping on the six-inch scale in the South-east of England (continue Reigate Sheet), in the Midlands district (finish Shrewsbury Sheet ; continue Dudley Sheet), and in Orkney and Shetland Islands. There will also be some primary six-inch revision of the Drift in the Saffron Walden Sheet ;

(*b*) revision of original six-inch mapping in the following coalfields and adjacent areas :—Lancashire, Yorkshire, Cumberland, Northumberland, Fifeshire, Ayrshire, Renfrewshire and Dumbartonshire (Sheet 30) ;

(*c*) investigation of underground water supplies ; verification of bore records ; examination of mineral resources ; and application of geophysical methods of surveying.

In concluding our Report for the year 1928 we desire to refer to the deaths of two very distinguished geologists, formerly members of the staff of the Geological Survey :—

(1) Sir Aubrey Strahan, who died on the 4th March, 1928, was Assistant to the Director of the Geological Survey in England

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from 1909 to 1914 and Director of the Survey and Museum from 1914 to July, 1920.

(2) Dr. John Horne, who died on the 30th May, 1928, was Assistant to the Director of the Geological Survey in Scotland from 1901 to 1911 and was a Member of this Board from 1920 to 1923.

The services which these officers gave are so well known in the geological world that no record of their achievements is required here. It is sufficient to say that their deaths mark a great loss to Geology.

F. G. OGILVIE,
Chairman.

5th April, 1929.

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SUMMARY OF PROGRESS OF THE GEOLOGICAL SURVEY AND MUSEUM FOR 1928

1. REPORT OF THE DIRECTOR

FIELD work during the past year has been concentrated on the task of revising the maps of British coalfields, though, as will be seen from the list of new publications, other areas have been by no means neglected. In such work progress is necessarily slow as the information which must be collected is not only great in amount but is often difficult to obtain, being scattered in many hands. All the plans of old mines, shaft sections and bore records that can be traced must be reduced to standard form and minutely scrutinized before a satisfactory map can be constructed. The Mining Industry Act of 1926 by giving compulsory access to all plans of working mines is proving useful occasionally, though the Survey has seldom been refused information from mine owners and mine managers who understand the nature of our work. More difficulty is often experienced in a coalfield that has been worked out and abandoned than in areas where mining operations are being actively carried on. The Mines Department, however, has been compiling a list of the plans of abandoned mines, as a safeguard against accidents in working, and this list when completed will make it easier to trace the original sources of information. The value of a survey of coalfields depends entirely on the thoroughness with which the records have been investigated. Some areas where the Geological Survey is now at work were originally surveyed more than sixty years ago; and whole districts and large parts of coalfields have been opened, developed and worked out since that time. The old maps consequently have little value except as a general indication of the structure of the ground and the sequence of the more important strata. The revision of such a district amounts practically to a new survey and no effort is being spared to verify all the old information and to complete it by collecting all details of importance revealed by subsequent work.

In five districts of England field units have been engaged during the year in coalfield revision. Dr. Bernard Smith and his staff have taken in hand the maps of the Aspatria district, which is the eastward continuation of the Maryport and Workington field. Formerly there was no effective survey of this ground on the six-inch scale, though one-inch maps were published. This area forms an outlying part of the Whitehaven or Cumberland coalfield, and when it is finished the revision of that coalfield will have been completed and the maps will be in a satisfactory state for the first time. Meanwhile, the publication of the Whitehaven six-inch maps

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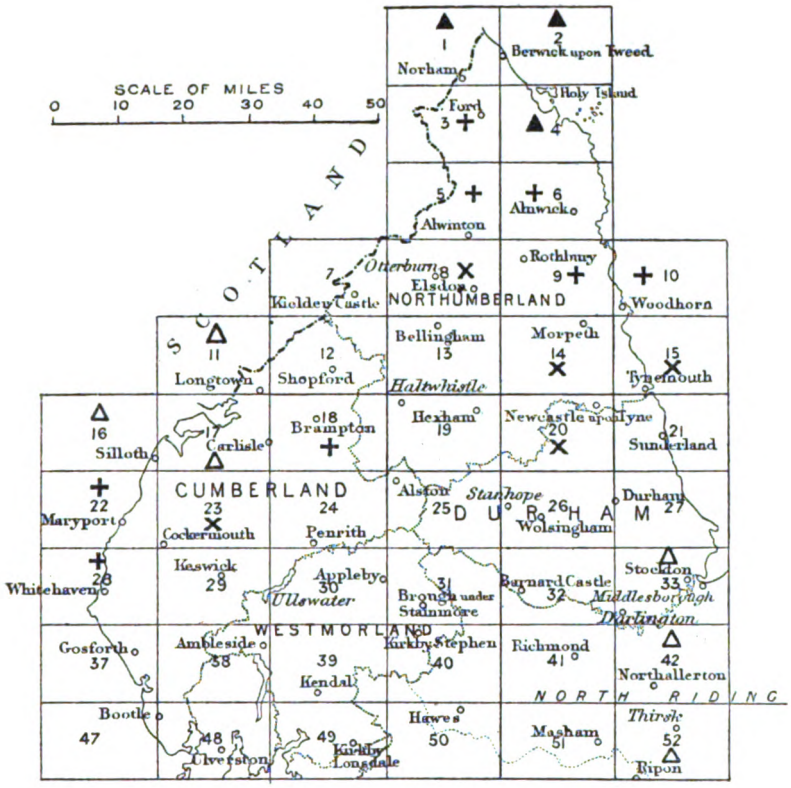

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▲	Published. Revised, colour-printed, S. and D.
△	Published. Revised, colour-printed, D.
+	Revised, not yet published.
×	Under revision, 1919.

FIG. 1.—*Index Map showing One-inch Geological Sheets of the North of England.*

is going on and the one-inch maps of Whitehaven (Sheet 28) and Maryport (Sheet 22) are in the press.

In Lancashire Dr. Wright and his staff, having finished the revision of the Rochdale and Manchester Sheets (76 and 85), are actively engaged in the Wigan Sheet (84). The structure is complicated by faulting, and much of the mining information is old and difficult to collect, but steady progress is being made and the field work may be finished next season. In this district there is little to be learned from surface outcrops but the underground information is very heavy, and the old six-inch maps, though excellent for their time, are no longer of value for practical purposes.

In the West Riding of Yorkshire Mr. Bromehead and his staff have completed the re-survey of the Glossop Sheet (86) and the

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six-inch maps are now being reduced to standard form for engraving. This is the second Sheet which has been revised by this unit, as the Huddersfield Sheet (77), completed two years ago, is now published

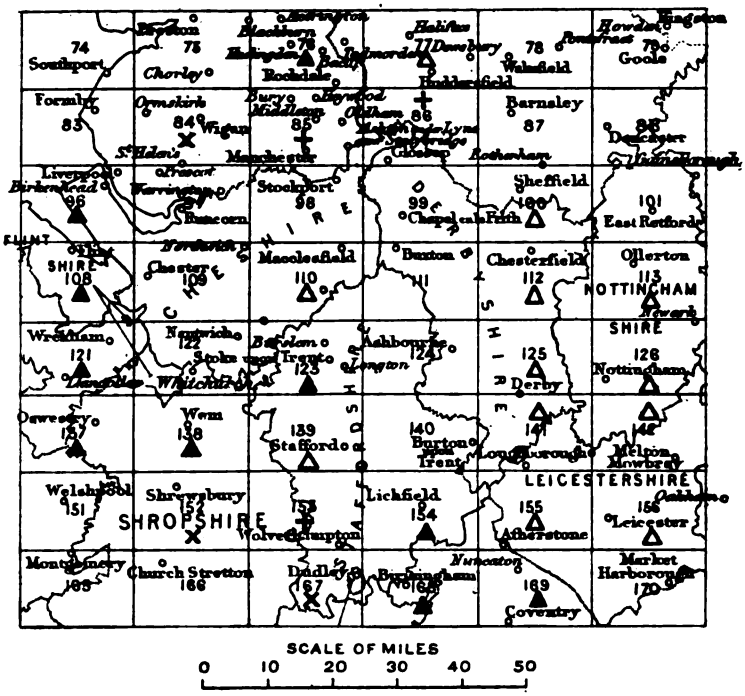

FIG. 2.—*Index map showing One-inch Geological Sheets of English Midlands.*

and the memoir describing it is almost ready to go to press. A revised edition of the memoir on the Concealed Coalfield of Yorkshire was also published two years ago. This indicates that steady progress is being made in providing reliable information on the structure and resources of this most important area of Coal Measures.

The progress of the Northumberland unit under Mr. Carruthers has been hampered to some extent by the death of Mr. Maden and the illness of another member of the staff. Consequently only one geologist has been employed in the field during a considerable part of the year. This group has undertaken first the revision of the limestone country from Berwick southwards, as it contains a

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group of coals, formerly worked in many places but now almost unwrought, about which the available information was previously deficient. Eight Sheets or parts of Sheets (1, 2, 3, 4, 5, 6, 9, 10) have been revised and three are published (1, 2 and 4); one more (Sheet 6, Alnwick) is in the press, and two are preparing for the engraver. At present it is more important to hasten the publication of the work that has been done than to press forward the field work. The Northumberland and Durham coalfield so far as composed of Coal Measures rocks has as yet only been touched in a few places.

In the West Midlands of England the unit formerly under Mr. Cantrill has continued its advance under Mr. C. H. Dinham, who has been transferred from Scotland. Its operations during the year were confined to the Shrewsbury Sheet (152) which contains the Shrewsbury, Leebotwood and part of the Coalbrookdale coalfields. In many respects this is a most interesting Sheet, as it embraces representatives of various formations ranging from the Pre-Cambrian to the Trias. Some interesting discoveries have been made in the older rocks by Mr. Pocock, for an account of which reference is made to Mr. Dinham's report. The revision of this Sheet will be completed early in 1929 and the Dudley Sheet (167) will be taken in hand. The revision of the Midlands coalfields will then have been practically finished.

In Scotland comparatively little field work has been done in the coalfields during the past year. The Ayrshire unit under Mr. Bailey re-surveyed a small outlying area of that coalfield around New Cumnock. It lies mostly beyond the boundaries of Sheet 14 (Ayr) but is connected geologically with the Coal Measures within that Sheet and a description of that ground is to be included in the Memoir on the Economic Geology of the Ayrshire Coalfields (Part IV). Mr. Ross, the only member of the Lanarkshire unit who was engaged in coalfield survey, has finished the six-inch mapping of the Douglas coalfield, an outlying area which is very important and of highly complex structure. In Fife Mr. Knox was the only geologist to do field work, and after his return from a three months stay in the Orkneys he carried on the revision of the coalfield about Leslie. This is the only important Scottish coalfield left to be revised and when it is finished the work remaining will be confined to small areas like Sanquhar and Campbeltown. The six-inch coalfield maps of Scotland are issuing steadily from the press, but before the new one-inch maps of Clackmannan, Fife and Renfrewshire can be published it will be necessary to make an examination of the pre-Carboniferous areas that occupy a large part of these Sheets.

Meanwhile, the production of the six-inch and one-inch maps and of the memoirs descriptive of the coalfields is being pushed forward. In Scotland there are certain conditions that render this work slow and laborious. One of these is the great abundance of bore-records; in some quarter-sheets of six square miles of coalfield there are over two hundred bores. This arises again from the broken

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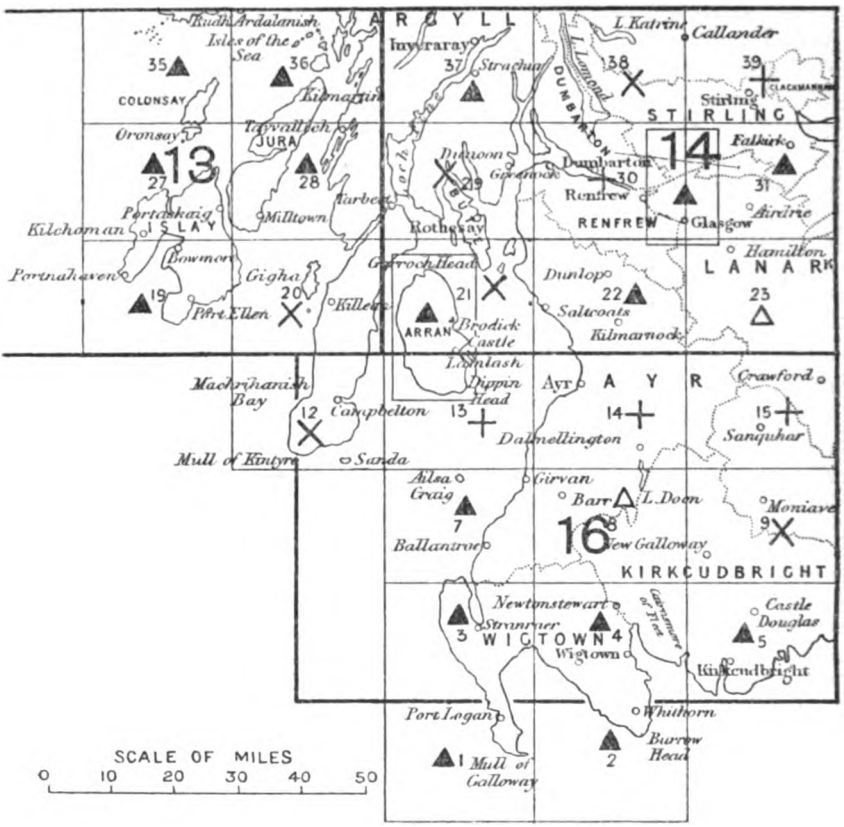

▲ Published, colour-printed.
△ Published, hand-coloured. Revised, colour-printed edition in the press.
\+ Published, hand-coloured. Revision in progress.
× Published, hand-coloured.

FIG. 3.—*Index map showing One-inch Geological Sheets of the South-west of Scotland.*

and faulted nature of the rocks, which renders mining operations hazardous and uncertain unless the ground is thoroughly proved by boring. Another important factor is the large size of the Scottish one-inch sheets, which cover nearly double the area of the corresponding sheets in England. The wide extent of igneous rocks requiring careful petrological study involves additional labour; for example, about one-half of the Kilmarnock Sheet (22) recently published is occupied by lavas and intrusions. Until the whole of this work is done it is not possible to produce a geological map showing the structure and relations of the rocks in a really satisfactory manner, likely to stand the test of time and meet the demands of industrial progress.

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In areas which are not productive or potential coalfields a large extent of ground has been revised during the past year. With the completion of the Aldershot Sheet (285) during the previous year the adjacent Reigate Sheet (286) was begun and Mr. Edmunds

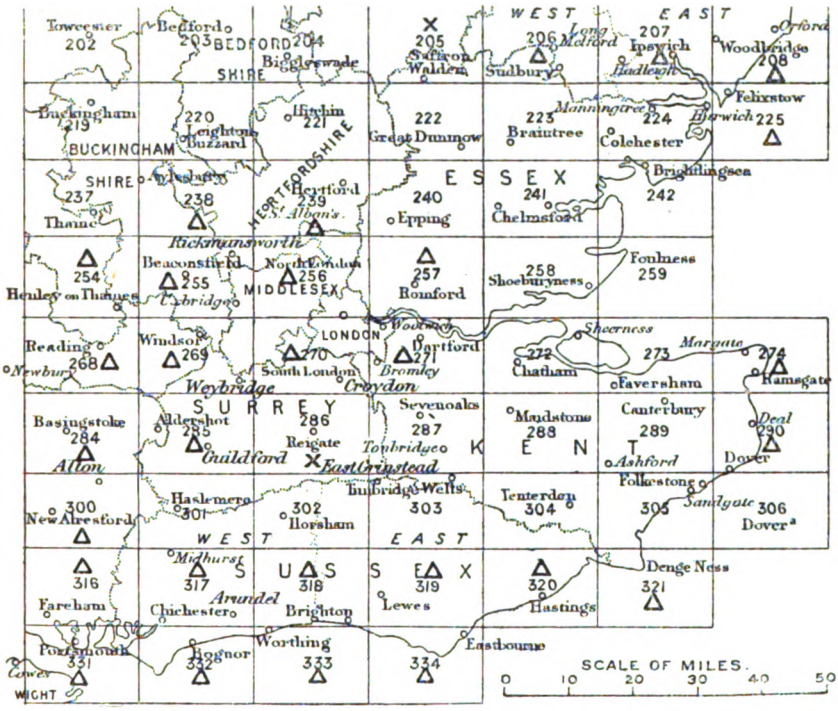

FIG. 4.—*Index map showing One-inch Geological Sheets of the South-east of England.*

and Mr. Dines have been employed there during most of the field season; for a short time towards the end of the year they had the assistance of Dr. Stubblefield, who joined the staff in October. Mr. Dines has also revised certain drift formations in the Moreton-in-Marsh Sheet (217) for which a memoir has been written by Mr. Linsdall Richardson. Mr. Osborne White is preparing a memoir on the Saffron Walden Sheet (205), and his work will be supplemented by some necessary revision during the present year. A new edition of the Torquay Memoir and one-inch Sheet (350) being rendered necessary by the exhaustion of the current edition, Mr. Lloyd has spent most of the year in that district gathering materials for a

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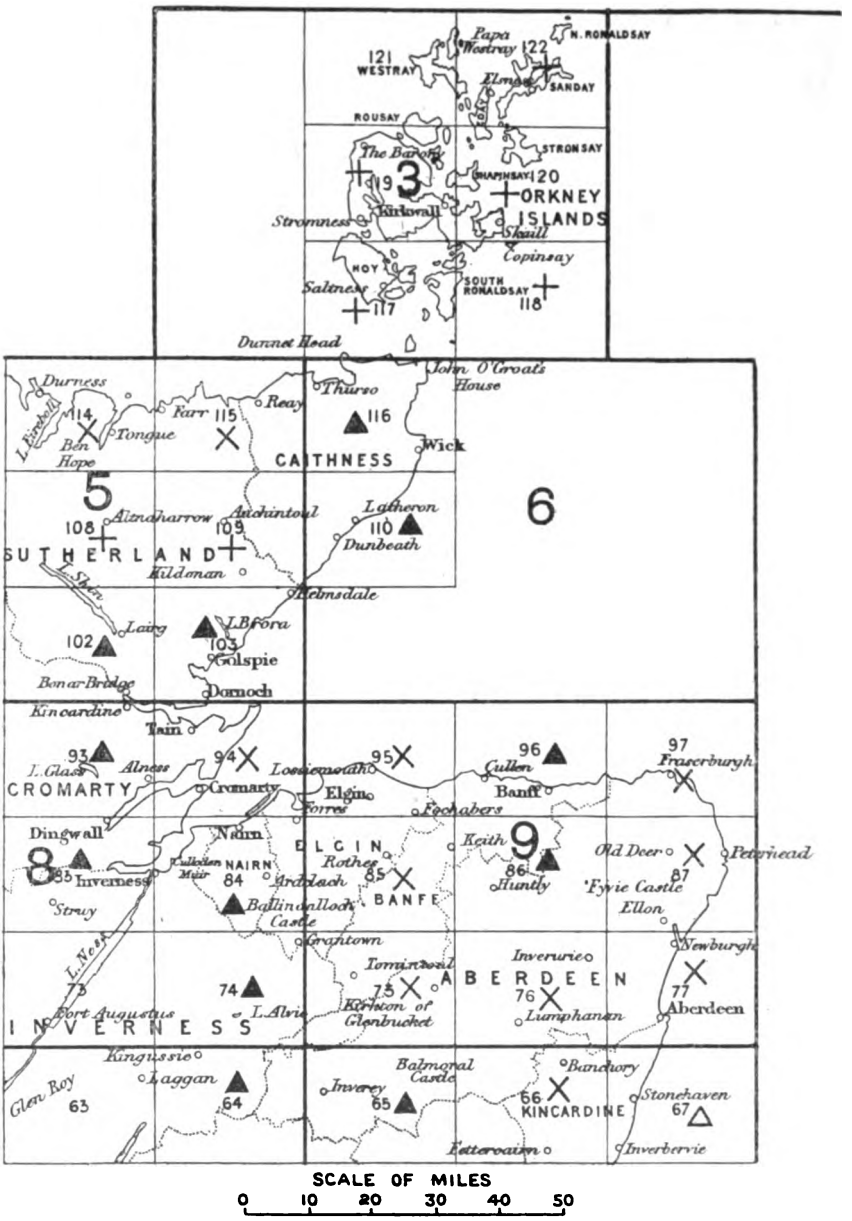

▲ Published, colour-printed.

△ Published, hand-coloured. Revised, colour-printed edition in the press.

\+ In preparation.

× Published, hand-coloured.

Maps without symbol unsurveyed.

FIG. 5.—*Index map showing One-inch Geological Sheets of the North-east of Scotland.*

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revision. Two other Sheets of which new editions are required are the Land's End (351-8) and Lizard Sheets (359) which are occupying the attention of Mr. Dewey and the Director.

The only mapping of ground not previously surveyed was done in the Orkney Islands. Mr. G. V. Wilson, recently appointed District Geologist, has now charge of that area, and had the assistance of two or three geologists for part of the season. The survey of nearly two-thirds of the county has been completed. It is expected that unless unforeseen circumstances delay progress the mapping of the Orkneys will be finished by the close of 1929.

Field work will also be undertaken in Shetland where as many Scottish geologists as it is possible to set free from coalfield work will be sent early in summer. They may have the assistance of a few members of the English staff for a short time as the field season in these islands is necessarily very short. When the results of the revision of the Scottish coalfields have been more fully published it will be possible to carry on the primary Highland mapping with more activity and to resume work in some districts where it was suspended for a time in order to accelerate the much needed resurvey of districts of economic importance.

It may be noted also that the staff of the late Professor Berry in the West of Scotland Agricultural College have continued their investigation of the distribution of soil-types in the Ayrshire province.

PUBLICATIONS

MAPS, VERTICAL SECTIONS, ETC.

Of the quarter-inch map of England and Wales one Sheet has appeared in a new edition. This Sheet (11) represents a large area, of which Derby is the centre, extending on the west to Crewe and on the east to Lincoln. It is the first quarter-inch Sheet to be printed with the new series of colours of which a complete scheme was drawn up last year. The objects aimed at in the revised scheme are greater simplicity in printing with more contrast in the colours. These small scale maps are often used as wall-diagrams for teaching classes and a vigorous colouring is desirable for this purpose. This map is on the whole successful, and the colours are well balanced, though some of the darker tints are not so transparent as in the previous edition. The alterations in the geology of this Sheet are not of great importance, though all the necessary changes have been introduced to represent the present state of our knowledge of the district.

Several other Sheets of this map are nearly sold out and new editions will be put in hand as soon as required. It is advisable to keep the old edition on sale for a time to enable purchasers to

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make up complete maps of large areas for which matched copies are often in demand.

The number of maps published during the year is considerable, though not so large as in the previous year. An exceptionally large number of English one-inch maps has passed through the press. The Huddersfield Sheet (77) is the first of the revision of the West Yorkshire Coalfield and is a sister map to the Rochdale Sheet (76) which was published last year. In this case, however, only one edition was necessary, as the superficial deposits in the Huddersfield district do not cover an extensive area. Another important coalfield sheet is Oswestry (137) which has been issued both in solid and drift editions. This Sheet completes the one-inch series of the North Wales coalfields, and the whole of the coalfields of Wales are now available in colour-printed maps of the new one-inch series. The corresponding memoir was nearly ready for sale at the close of the year. The revised six-inch maps of the North Wales coalfields have all been published.

The other English one-inch sheets in the subjoined list, Sudbury (206), Woodbridge (208), Felixstowe (225), Ramsgate (274), Dover (290), Hastings (320), Dungeness (321) and Aldershot (285), have all received some revision to bring them up to date, but only the Aldershot Sheet is completely re-surveyed on the scale of six inches to one mile. The publication of these new geological maps of the South and East of England is a matter of considerable importance as these districts are populous, and their agricultural industries are rich and varied. Many requests for information about these counties are received from people in search of water supply, or for suitable residential districts, and the new maps are much in demand. With the completion of the re-survey of London and its environs attention has been directed to the principal residential districts and especially to the coast resorts and it is hoped to make steady progress with the preparation of new maps of the south-eastern counties.

The Windsor map, which was published in the New Series in 1920, has recently been sold out and a new edition is in the press in which certain alterations are being made in the colour-printing, while the geology of the map is essentially unchanged.

The most important Scottish map to be published during the year is the Kilmarnock Sheet (22) which was issued in both solid and drift editions. This sheet is large and complex and the varied geology necessitated a very elaborate series of colours. A further edition is in the press showing the physical types of soil in the Kilmarnock area. These three maps taken together will form the most complete representation of any district that the Geological Survey has yet published.

As the Edinburgh Sheet (32) issued in 1910 was nearly sold out and the old edition was not completely satisfactory it was decided to prepare at once a drift edition showing accurately all the

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superficial deposits, which cover more than nine-tenths of the region. That map has been published and meanwhile the stocks of the old map have been exhausted. A solid edition of that Sheet is now engraving and will be issued in 1929. In the former edition the attempt to represent both solid and drift on a single map resulted in obscurity owing to excessive detail, and the new maps are of the same type as those of Kilmarnock (22) which are believed to be better in all respects. The new solid map is not based on a complete re-survey, but will differ from the previous edition in several respects, as all the information that has been obtained since the previous edition was issued has been incorporated. In the oil-shale fields, for example, there are important changes owing to the additional particulars collected from the mining companies during the preparation of the third edition of the memoir on the Oil-Shales of the Lothians published in 1927.

Of the six-inch maps which are intended to show the detailed geology of the coalfields a very satisfactory number has passed through the press during the year. Ten of these are from Cumberland (principally in the Whitehaven and Maryport districts), and cover the most difficult and most productive parts of that field. Seven sheets are from the Manchester district of Lancashire; eight are from Northumberland; seven are from the Huddersfield and Dewsbury district in Yorkshire; six are from Shropshire. Four maps of the South Wales coalfield have also been published and indicate the continuation of a revision of that field which makes the third survey of South Wales.

Among the Scottish six-inch maps published during the year there are eleven sheets of Ayrshire which carry the publication of that coalfield well forward towards completion. The other eight maps represent parts of Clackmannan, Fife and Stirling. A special map on the scale of four miles to one inch, showing the six-inch quarter sheets of the revised coalfield survey, has been prepared to serve as an index map for office use. As such a map will undoubtedly be of interest for reference it is expected that it will ultimately be published along with a list of the new six-inch maps of Scottish coalfields when further progress has been made with the publication of that series.

Three sheets of vertical sections of strata were published during the year and four others are in the press. Requests were received from South Wales for certain vertical sections of shafts and borings in that field which were no longer on sale, and as they are still of interest they received a few corrections and additions and were sent to be reprinted. A new plate of sections from the Abergavenny district has also been drawn up by Dr. Robertson, based on information collected during his recent revision of that sheet in connexion with the second edition of the Sheet memoir which was issued in 1927. This will be printed in a simple colour scheme, like several other sheets of vertical sections recently issued by the Geological

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Survey. It is found that these coloured sheets are more rapidly engraved and printed and have certain other advantages over the old sheets which were uncoloured but had the stratal characters represented by ornament in black and white. These latter involved a great expenditure of time in drawing the ornament. In Scotland also colour-printed sheets of vertical sections have now found favour. One has already been published for North Ayrshire and another is in hand for Central Ayrshire. The single Scottish sheet of Vertical Sections published during the past year is the last of a series designed to illustrate the new six-inch maps of the Central Coalfield and the set of economic memoirs relating to that field.

Memoirs

As will be seen from the list of published memoirs, there has been great activity on the part of the English Survey in this connexion during the past year. Thirteen volumes have been sent out, including the *Summary of Progress* and a revised edition of the List of Memoirs, Maps and Sections. These include two important contributions to British palaeontology, which, though written by experts who are not now on our regular staff, are based on the collections of the Survey in London and in Edinburgh. Very careful search of all sources of information has been made, however, in preparing these monographs, and the authors are much indebted to the officers of the British Museum, Royal Scottish Museum, Sedgwick Museum and other curators of British collections of fossils for granting full access to the materials in their custody and for many other services of a valuable kind.

Three memoirs on the Water Supply of English counties have been published during the year. Two of these have been compiled by Mr. L. Richardson and the third by Mr. Edmunds. These memoirs involve much labour in collecting and checking the records, and though they appeal to only a limited public they serve a very useful purpose and are much appreciated by well borers, medical officers of health and water engineers. In addition to this they contain a very large amount of detailed and accurate information regarding the strata of the counties which they describe, and the work spent in bringing together the information is fully justified by the importance of the subject. Four other water supply memoirs are in the press or in preparation and will be published when complete, viz., Derbyshire, Worcestershire, Gloucestershire and Leicestershire. For three of these we are indebted to the assistance of Mr. Richardson, who has made use of all the collected information in the Survey offices and has added much valuable material to it by strenuous enquiry from all available sources. Most of the recent memoirs of this series have the principal borings numbered and corresponding numbers are placed on a series of reference maps which are open for consultation by the public in the Survey library

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and give the exact site of the boring when that is accurately known. It is a matter of considerable importance to know the exact position of a boring, and this is usually not difficult to ascertain when the boring is in use and yields large quantities of water. But some of the older borings which were not successful or were abandoned can no longer be located; in such cases the information may be of interest to a geologist, and especially if the country is traversed by faults may give very significant indications as to the distribution of underground water resources and the best situations in which to make search for new supplies.

Three memoirs on the geology of the South and East of England have also made their appearance, one by Professor Boswell, of Liverpool University, and two by Mr. H. J. Osborne White. Along with these memoirs new colour-printed versions of the corresponding one-inch maps have been issued with such alterations as were considered desirable to bring them up to date, but a complete re-survey of the ground on the six-inch scale was not undertaken because it seemed unnecessary.

Both the Woodbridge and the Hastings district are classic geological country and these short and readable descriptions give the most recent views on the structure and problems of these well-known areas with a summary of the literature and a description of the new colour-printed map.

Two coalfield memoirs dealing with the West Midlands and an adjacent portion of North Wales are included in the list of the year's publications. These memoirs are full of detail regarding the geology of the coalfields, and have taken much labour in compiling. Another memoir of this series, on the Oswestry Sheet (137) is in the press, and this will complete the description of the coalfields of North Wales, bringing to an end a piece of work that was interrupted by the War and has suffered considerable delay owing to many unforeseen circumstances. Mr. T. C. Cantrill, who has now retired from the staff, was fortunately able to complete the editorial work, and make the manuscripts ready for the press before his retirement.

One memoir on Scottish geology was published during the year, an account of the Island of Arran by Dr. G. W. Tyrrell, of Glasgow University. No complete account of this most interesting island had previously been issued by the Geological Survey, though a volume on North Arran by W. Gunn and Dr. A. Harker was published in 1903 and has been out of print for a year or two. Dr. Tyrrell's services in this connexion were most valuable, for he had an excellent knowledge of the geology and petrology of Arran, and he made full use of the original maps of Gunn and the notes which that geologist had left in preparation for a memoir on the southern half of the island. The new Arran memoir made an opportune appearance and was welcomed by the geologists who took part in the meeting of the British Association in Glasgow in September. It furnishes a complete description of the area included in the special

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colour-printed map of Arran which was based on the survey by William Gunn. For the first time a complete account of the geology of Arran is now at the disposal of visitors to the island and to students of volcanic rocks in general. The Tertiary volcanic centres of Skye, Rum, Mull and Arran are all described in memoirs of the Geological Survey, and when the forthcoming volume on Ardnamurchan is printed no department of British geology will have been more fully discussed and illustrated.

Special Reports on Mineral Resources

No addition to this series has been made during the past year. Thirty volumes have now been published since 1915, and several of them have passed through three editions. More than one of these volumes is now nearly sold out and new editions will have to be prepared when a sufficient amount of fresh information has been collected to justify that course. The great activity that marked the exploitation of British mineral deposits towards the close of the War and for a time thereafter has considerably diminished, and the demands for information are not so insistent as they were. It is mostly from new mining developments that useful information can be obtained, and though efforts are made to keep in touch with the advance of exploration and mining, the growth of knowledge is slow when the industry is inactive. At present this series may be regarded as fairly comprehensive and sufficiently up-to-date to fulfil its purpose. One new volume is in the press—an account of English Ball Clays by Dr. A. Scott, of the Potteries Laboratory. This will form a useful companion volume to Mr. J. Allen Howe's memoir on Kaolin and China Clay. Both series of deposits are the foundation of important British industries, and the memoirs in question furnish adequate descriptions of the mineralogy, geology, distribution, origin and special characters of the British china-clays and pottery clays with numerous chemical analyses prepared specially in the Survey laboratory or by expert analysts.

In connection with the series of Economic Memoirs and Special Reports on Mineral Resources the preparation of a handbook on Attrition Tests of British Road-stones may here be mentioned. The Geological Survey has a very fine collection of British road-stones, amounting to over 1,200 in number, all of which have been sliced and examined microscopically and tested by various methods as regards durability, specific gravity, and other physical characters. This collection was initiated by Mr. E. J. Lovegrove in 1903 when he was Borough Engineer of Hornsey and the results of the first 213 were published in 1906, accompanied by petrographical descriptions by Mr. Howe and Sir John Flett. Subsequently Mr. Lovegrove carried on the work and his complete series of tests number 468. He has presented all the specimens to the Museum of Practical Geology, where a representative set of rocks with tables, maps and

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photographs has been exhibited for several years. This exhibit has now been removed to a more convenient place in the Museum and re-arranged by Miss E. M. Guppy, who has assisted in the preparation of a new handbook to the Lovegrove collection which is now in the press.

When in 1911 the Road Board took up the testing of road-stones at the National Physical Laboratory, Teddington, Mr. Lovegrove discontinued his series of tests. Road-stone testing as practised at Teddington is not conducted by the same methods as those invented and used by Mr. Lovegrove, and consequently the numerical results cannot be strictly compared. The Lovegrove Collection is complete in itself and represents the first practical experiments in this branch of stone investigation in Great Britain. As the descriptive handbook, published in 1906, is sold out and many enquiries had been received for a new and revised edition it is felt that this little book will serve a useful purpose.

Water Supply Memoirs

As is indicated on page 29 there have been several Water Supply Memoirs published during the year, and a good deal of work has also been done in the preparation of memoirs on four other counties—Derbyshire, Worcestershire, Gloucestershire and Leicestershire. These four memoirs will probably go to press in 1929. The new edition of London Wells which has been in preparation for some time has not yet gone to press as the current edition is not quite sold out. Very numerous enquiries are being received about the superficial formations of the London district, owing partly, no doubt, to the large amount of building that is going on, and new information flows in steadily from many sources regarding excavations, borings and wells. The economic importance of this is obvious, and the Geological Survey is much indebted to builders, architects, well-sinkers and borers for the readiness with which they supply particulars. The inspectors of the London County Council have in all cases been most helpful and neglect no opportunity to record observations on the formations underlying London.

Many enquiries are also received from people in search of residences in and around London who wish to know the conditions of soil and subsoil in the various suburbs and surrounding districts in respect not only of water supply but also of amenity and freedom from waterlogged conditions.

The series of water supply memoirs regarding the south-east of England is now reasonably complete, as will be seen from the map on page 22. These districts were taken first as they are the most dependent on underground sources for their water supplies. In counties where the Chalk and the Greensand are well developed the problem of obtaining supplies is often easily solved by a knowledge of the geological conditions. The memoirs more recently published

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FIG. 6.—*Index Map showing areas described in Water-supply Memoirs.*

1, 2. Bedfordshire and Northamptonshire.
3. Berkshire.
4, 5. Buckinghamshire and Hertfordshire.
6, 7, 8. Cambridgeshire, Huntingdonshire and Rutland.
9. Dorset.
10. Essex.
11. Hampshire.
12. Kent.
13. Lincolnshire.
14. London Wells.
15. Norfolk.
16. Nottinghamshire.
17. Oxfordshire.
18. Somerset.
19. Suffolk.
20. Surrey.
21. Sussex.
22. Warwickshire.
23. Wiltshire.
24. Yorkshire, East Riding, etc.
25. Derbyshire. } In preparation.
26. Gloucestershire. } In preparation.
27. Leicestershire. } In preparation.
28. Worcestershire. } In preparation.

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have referred to Midland and Western counties where the geological structure is more complex and the problems are often more difficult of solution. The series of twenty-four memoirs published and in preparation on British water supplies from underground sources are standard reference works to all who are interested in questions of this kind, and represent a valuable contribution to British hydrography. These memoirs form, however, only a part of the information which the Survey has collected as there is a great mass of unprinted material in the records contained in the Survey offices. Enquiries are received in great numbers and all the relative data in our possession are freely placed at the service of the engineers and others who desire to obtain such information. In turn we receive from all the principal well-sinkers and borers in Britain the fullest possible information regarding new wells and bores, and this department of the Survey's work, though little known to the general public, is one that serves a most useful purpose and could be carried on by no other agency so efficiently and with so little expenditure.

The following maps, vertical sections and memoirs were published in 1928 :—

I.—Maps

English and Welsh Maps published in 1928

¼ inch to 1 mile :—

Sheet 11.—Derby, Lincoln, Sheffield, Stafford. (*Solid Edition, Revised.*)

1 inch to 1 mile :—

Sheet 77.—Huddersfield (*Drift Edition*). Originally published on Old Series map. Re-surveyed by D. A. Wray, J. V. Stephens, Wilfrid Edwards and W. Lloyd ; C. E. N. Bromehead, District Geologist.

Sheet 137.—Oswestry (*Solid and Drift Editions*). Original survey on one-inch scale. Re-surveyed by C. B. Wedd, B. Smith, L. J. Wills, W. B. R. King and D. A. Wray ; G. W. Lamplugh and T. C. Cantrill, District Geologists.

Sheet 206.—Sudbury (*Drift Edition*). Original survey by F. J. Bennett, J. H. Blake, W. H. Dalton, W. H. Penning and W. Whitaker. Part re-surveyed by P. G. H. Boswell. Transferred to the New Series map with minor corrections.

Sheet 208.—Woodbridge (*Drift Edition*). Original survey by W. Whitaker and W. H. Dalton. Transferred to the New Series map.

Sheet 225.—Felixstowe (*Drift Edition*). Original survey by W. Whitaker and W. H. Dalton. Transferred to the New Series map.

Sheet 274.—Ramsgate (*Drift Edition*). Original survey on one-inch scale. Transferred to the New Series map with additions by F. H. Edmunds.

Sheet 285.—Aldershot (*Drift Edition*). Original survey on one-inch scale. Re-surveyed by C. E. N. Bromehead, H. G. Dines and F. H. Edmunds ; H. Dewey, District Geologist.

Sheet 290.—Dover (*Drift Edition*). Original survey on one-inch scale. Transferred to the New Series map with additions by H. G. Dines and F. H. Edmunds.

Sheet 320.—Hastings (*Drift Edition*). Original survey on one-inch scale. Transferred to the New Series map.

Sheet 321.—Dungeness (*Drift Edition*). Original survey on one-inch scale. Transferred to the New Series map.

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6 inches to 1 mile (coalfield maps) :—

Cumberland, 19 N.W.—Hartleyburn Common. Original survey by D. Burns. Re-surveyed by F. M. Trotter; B. Smith, District Geologist.

Cumberland, 44 N.E.—Maryport. Original survey by R. Russell. Re-surveyed by T. Eastwood; B. Smith, District Geologist.

Cumberland, 44 S.E.—Flimby. Original survey by R. Russell. Re-surveyed by T. Eastwood; B. Smith, District Geologist.

Cumberland, 45 N.W.—Ellenborough. Original survey by R. Russell. Re-surveyed by T. Eastwood; B. Smith, District Geologist.

Cumberland, 45 S.W.—Broughton Moor. Original survey by R. Russell. Re-surveyed by T. Eastwood; B. Smith, District Geologist.

Cumberland, 54 N.W.—Broughton. Original survey by R. Russell. Carboniferous Rocks revised by J. G. Goodchild. Re-surveyed by T. Eastwood; B. Smith, District Geologist.

Cumberland, 54 S.W.—Little Clifton. Original survey by R. Russell. Millstone Grit and older rocks revised by J. G. Goodchild. Re-surveyed by E. E. L. Dixon; B. Smith, District Geologist.

Cumberland, 62 N.W.—Branthwaite. Original survey by R. Russell. Revised by A. Strahan. Re-surveyed by E. E. L. Dixon; B. Smith, District Geologist.

Cumberland, 62 S.W.—Kidburngill. Original survey by R. Russell. Revised by A. Strahan. Re-surveyed by E. E. L. Dixon; B. Smith, District Geologist.

Cumberland, 72 N.E.—Egremont. Original survey by W. T. Aveline and R. Russell. Part revised by A. Strahan. Re-surveyed by B. Smith, District Geologist.

Glamorganshire, 12 N.E. (Mon. 16 N.E.).—Pontlottyn (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Lancashire, 87 N.W.—Bradshaw. Original survey by E. Hull. Re-surveyed by W. B. Wright and R. C. B. Jones; W. B. Wright, District Geologist.

Lancashire, 87 N.E.—Tottington. Original survey by E. Hull. Re-surveyed by W. B. Wright and R. L. Sherlock; W. B. Wright, District Geologist.

Lancashire, 87 S.W.—Bolton. Original survey by E. Hull. Re-surveyed by R. C. B. Jones; W. B. Wright, District Geologist.

Lancashire, 88 N.W.—Birtle. Original survey by E. Hull. Re-surveyed by L. H. Tonks; W. B. Wright, District Geologist.

Lancashire, 88 S.W.—Bury. Original survey by E. Hull. Re-surveyed by L. H. Tonks; W. B. Wright, District Geologist.

Lancashire, 95 N.W.—Farnworth. Original survey by E. Hull. Re-surveyed by R. C. B. Jones; W. B. Wright, District Geologist.

Lancashire, 96 N.W.—Whitefield. Original survey by E. Hull. Re-surveyed by L. H. Tonks; W. B. Wright, District Geologist.

Monmouthshire, 17 N.E.—Blaenau-Gwent (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Monmouthshire, 17 S.E.—Aberbeeg (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Monmouthshire, 18 S.E.—Pontypool (*Revised Edition*). Original survey by A. Strahan. Revised by T. Robertson.

Northumberland, N. 10 N.E.—Ford. Original survey by W. Gunn. Revised by R. G. Carruthers and F. Marsden; R. G. Carruthers, District Geologist.

Northumberland, N. 11 N.W.—Bar Moor. Original survey by W. Gunn. Revised by R. G. Carruthers, C. H. Dinham and F. Marsden; R. G. Carruthers, District Geologist.

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Northumberland, N. 34 N.E.—Abberwick. Original survey by W. Topley. Revised by R. G. Carruthers, W. Anderson and J. Maden; R. G. Carruthers, District Geologist.

Northumberland, N. 34 S.E.—Edlingham. Original survey by W. Topley. Revised by W. Anderson and J. Maden; R. G. Carruthers, District Geologist.

Northumberland, N. 35 S.E.—High Buston. Original survey by W. Topley. Revised by R. G. Carruthers, C. H. Dinham and J. Maden; R. G. Carruthers, District Geologist.

Northumberland, N. 43 N.W.—Newton-on-the-Moor. Original survey by W. Gunn and W. Topley. Revised by C. H. Dinham, A. Fowler and J. Maden; R. G. Carruthers, District Geologist.

Northumberland, N. 43 S.E.—Acklington. Original survey by W. Topley. Revised by A. Fowler; R. G. Carruthers, District Geologist.

Northumberland, N. 49 S.E.—Blagdonburn. Original survey by W. Topley. Revised by J. Maden; R. G. Carruthers, District Geologist.

Shropshire, 12 N.W.—Selattyn. Surveyed by L. J. Wills and C. B. Wedd; G. W. Lamplugh, District Geologist.

Shropshire, 12 N.E.—New Marton. Surveyed by L. J. Wills and C. B. Wedd; T. C. Cantrill, District Geologist.

Shropshire, 12 S.W.—Oswestry. Surveyed by C. B. Wedd; T. C. Cantrill, District Geologist.

Shropshire, 12 S.E.—Whittington. Surveyed by C. B. Wedd; T. C. Cantrill, District Geologist.

Shropshire, 18 N.E.—Llansilin. Surveyed by B. Smith and C. B. Wedd; T. C. Cantrill, District Geologist.

Shropshire, 19 S.W.—Llynclys. Surveyed by C. B. Wedd; T. C. Cantrill, District Geologist.

Yorkshire, 215 N.E.—Denholme. Original survey by J. R. Dakyns, J. C. Ward, C. Fox-Strangways and W. H. Dalton. Re-surveyed by J. V. Stephens; C. N. Bromehead, District Geologist.

Yorkshire, 215 S.E.—Mixenden. Original survey by J. R. Dakyns, J. C. Ward, C. Fox-Strangways and W. H. Dalton. Re-surveyed by J. V. Stephens; C. N. Bromehead, District Geologist.

Yorkshire, 246 S.E.—Huddersfield. Original survey by J. C. Ward and R. Russell. Re-surveyed by D. A. Wray; C. N. Bromehead, District Geologist.

Yorkshire, 247 N.W.—Mirfield. Original survey by A. H. Green, J. C. Ward and R. Russell. Re-surveyed by C. N. Bromehead, District Geologist.

Yorkshire, 247 N.E.—Dewsbury. Original survey by A. H. Green, J. C. Ward and R. Russell. Re-surveyed by C. N. Bromehead, District Geologist.

Yorkshire, 260 N.E.—Almondbury. Original survey by J. C. Ward and R. Russell. Re-surveyed by D. A. Wray; C. N. Bromehead, District Geologist.

Yorkshire, 261 N.W.—Kirkburton. Original survey by A. H. Green, J. C. Ward and R. Russell. Re-surveyed by D. A. Wray; C. N. Bromehead, District Geologist.

Scottish maps published in 1928

1 inch to 1 mile :—

Sheet 22.—Kilmarnock (*Solid and Drift Editions*). Original survey by A. Geikie and J. Geikie. Revised by C. T. Clough, E. B. Bailey, E. M. Anderson, R. G. Carruthers, C. H. Dinham, J. E. Richey, G. V. Wilson, G. A. Burnett, V. A. Eyles, J. B. Simpson, A. G. MacGregor and J. Phemister; C. T. Clough and E. B. Bailey, District Geologists.

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Sheet 32.—Edinburgh (*Drift Edition*). Original survey by A. Geikie and H. H. Howell. Revised by Sir A. Geikie, H. H. Howell, B. N. Peach, J. S. Grant-Wilson and H. M. Cadell. Further revision by B. N. Peach, C. T. Clough, L. W. Hinxman, J. S. Grant-Wilson, W. Gibson, E. H. Cunningham-Craig, C. B. Crampton, H. B. Muff, E. B. Bailey, E. M. Anderson and G. W. Grabham. (*New Colour-printed edition.*)

6 inches to 1 mile (coalfield maps) :—

Ayrshire, 26 S.E.—Glenbuck. Original survey by B. N. Peach. Revised by E. M. Anderson, G. V. Wilson and G. Ross ; M. Macgregor and J. E. Richey, District Geologists.

Ayrshire, 30 N.E.—Burnfoot Moor. Original survey by B. N. Peach. Revised by G. V. Wilson ; M. Macgregor, District Geologist.

Ayrshire, 31 N.W.—Muirkirk. Original survey by B. N. Peach. Revised by G. V. Wilson ; M. Macgregor, District Geologist.

Ayrshire, 34 S.W.—Coylton. Original survey by A. Geikie. Revised by V. A. Eyles ; E. B. Bailey, District Geologist.

Ayrshire, 40 N.W.—Craigs of Kyle. Original survey by J. Geikie. Revised by V. A. Eyles ; E. B. Bailey, District Geologist.

Ayrshire, 40 S.W.—Patna (N. of). Original survey by J. Geikie. Revised by A. G. Macgregor ; E. B. Bailey, District Geologist.

Ayrshire, 40 S.E.—Rankinston. Original survey by J. Geikie. Revised by J. B. Simpson ; E. B. Bailey, District Geologist.

Ayrshire, 41 N.W.—Knockdunder. Original survey by J. Geikie. Revised by J. B. Simpson ; E. B. Bailey, District Geologist.

Ayrshire, 46 N.W.—Patna, Waterside. Original survey by J. Geikie. Revised by A. G. Macgregor ; E. B. Bailey, District Geologist.

Ayrshire, 50 N.E.—Wallacetown. Original survey by A. Geikie. Ordovician and Silurian revised by B. N. Peach and J. Horne. Post-Silurian by J. E. Richey ; E. B. Bailey, District Geologist.

Ayrshire, 50 S.E.—New Dailly. Original survey by A. Geikie. Ordovician and Silurian revised by B. N. Peach and J. Horne. Post-Silurian by J. E. Richey ; E. B. Bailey, District Geologist.

Clackmannanshire, 139 N.W.—Blackgrange. Original survey by B. N. Peach. Revised by C. H. Dinham and H. H. Read ; C. H. Dinham, District Geologist.

Clackmannanshire, 139 S.E.—Mouth of Black Devon, Dunmore. Original survey by B. N. Peach. Revised by C. H. Dinham, H. H. Head and D. Haldane ; C. H. Dinham, District Geologist.

Fifeshire, 34 S.E.—Cowdenbeath. Original survey by H. H. Howell and A. Geikie. Revised by J. K. Allan ; C. H. Dinham, District Geologist.

Fifeshire, 37 N.W.—Kincardine-on-Forth. Original survey by B. N. Peach. Revised by C. B. Crampton, C. H. Dinham and D. Haldane ; C. H. Dinham, District Geologist.

Fifeshire (40 N.E. and 41 N.W.)—Kinghorn. Original survey by H. H. Howell and A. Geikie. Revised by J. Knox ; C. H. Dinham, District Geologist.

Fifeshire and Kinross-shire, 34 N.E.—Kelty. Original survey by H. H. Howell and A. Geikie. Revised by J. K. Allan ; C. H. Dinham, District Geologist.

Stirlingshire, 10 S.E.—Stirling (N. part). Original survey by B. N. Peach. Revised by C. H. Dinham, H. H. Read and D. Haldane ; C. H. Dinham, District Geologist.

Stirlingshire, 18 S.W.—Cowie. Original survey by B. N. Peach. Revised by C. H. Dinham, District Geologist.

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Manuscript copies of the following maps on the scale of six inches to one mile were deposited in the Library for public reference. These maps are not to be published. The English maps are deposited in the head office in London. The Scottish maps are deposited in the Edinburgh Office.

English manuscript maps deposited for reference

Denbighshire, 38 S.W. (part); 41 N.W. (part), N.E., S.W. (part), S.E.; 42 N.W., N.E., S.W., S.E.; 44 N.W., N.E. (part).

Hampshire, 76 N.W., N.E., S.W., S.E.

Montgomeryshire, 5 N.W. (part), N.E., S.W. (part), S.E.; 6 S.W.; 9 N.W. (part), N.E., S.W. (part), S.E.; 10 N.W., N.E. (Shropshire, 25 N.E.), S.W., S.E.

Northumberland, N. 5 S.E.; N. 6 S.W.; N. 10 N.W., S.W., S.E.; N. 14 N.W., N.E., S.E.; N. 15 N.W., N.E., S.W., S.E.; N. 19 N.E., S.E.; N. 20 N.W., N.E., S.W., S.E.; (N. 25 S.W. and S.E.); N. 26 N.W., N.E., S.W.

Shropshire, 11 N.E. (part), S.E.; 18 S.E.; 19 N.E., S.E.; 26 N.W. (Montgomery, 11 N.W.), N.E., S.W. (Montgomery, 11 S.W.), S.E.; 36 N.W.; 37 N.W., S.W., S.E.; 44 N.W., N.E., S.W., S.E.; 51 N.W., N.E., S.W., S.E.; 52 N.W., N.E., S.W., S.E.

Staffordshire, 49 N.W., N.E., S.E.; 50 N.W., N.E., S.W., S.E.; 55 N.E., S.E.; 56 N.W., N.E., S.W., S.E.,; 61 N.W., N.E., S.W. (part), S.E.; 62 N.W., S.W.

Yorkshire, 215 N.W., S.W.; 245 S.W.; 259 N.W.

Scottish Manuscript maps deposited for reference

Argyllshire, 13 S.E.; 14; 15 N.W., S.W.; 23 N.E.; 24; 25 N.W., S.W.

Argyllshire (Coll and Tiree), 36 N.E., S.W., S.E.; 49 N.E., S.W., S.E.; 50 N.W., N.E., S.W.

Argyllshire (Mull), 96.

Ayrshire, 9 S.W., S.E.; 13 N.E.; 14 N.W., S.W., S.E.; 19 N.W.; 25 S.W.; 30 N.W.; 43 S.E.; 44 N.W., S.W.; 50 N.W.

Berwickshire, 7 N.E., S.W., (S.E. and 13a); 8; 9; 10; 14; 15; 16; 20; 21; 22.

Fifeshire, 37 S.W.

Lanarkshire, 26 N.W., S.W.; 34 N.W.; 39 S.E.; 40 N.W.

Renfrewshire, 16 S.W., S.E.; 17 S.W.; 18 N.E.; 19.

Sutherlandshire, 36; 37; 45; 46; 47; 55; 56; 57; 65; 66; 67; 68 S.W.; 76; 77; 78; 79.

List of Maps in the press at the close of 1928

English maps in the press

1 inch to 1 mile :—

Sheet 6.—Alnwick (*Solid and Drift Editions*).

Sheet 22—Maryport (*Solid and Drift Editions*).

Sheet 28.—Whitehaven (*Solid Edition*).

Sheet 153.—Wolverhampton (*Solid and Drift Editions*).

Sheet 217.—Moreton in Marsh (*Drift Edition*).

Sheet 269.—Windsor (*New Drift Edition*).

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6 inches to 1 mile (coalfield maps) :—

Cumberland, 13 S.W.
Lancashire, 87 S.E. ; 88 N.E., S.E. ; 95 N.E., S.W., S.E. ; 96 N.E., S.W., S.E. ; 97 N.W., S.W. ; 103 N.W., N.E. ; 104 N.W., N.E., S.W., S.E. ; 105 N.W., S.W.
Northumberland, N.28 N.E., N. 29 N.W., S.W., S.E. ; N. 34 S.W. ; N. 35 N.W., N.E., S.W. ; N. 42 N.W., N.E. ; N. 43 N.E. ; N. 88 N.E. ; (N. 97 S.W. and S.E.).
Shropshire, 19 N.W. ; 36 N.E., S.E. ; 43 N.E., S.E.
Staffordshire, 62 N.E.

Scottish maps in the press

Index Map :—

Central Coalfield of Scotland showing 6-inch and 1-inch Sheets, on scale of 4 miles to an inch.

1 inch to 1 mile :—

Sheet 8.—Carrick.
Sheet 22.—Kilmarnock (*Soil Texture Edition*).
Sheet 23.—Hamilton (*Solid and Drift Editions*).
Sheet 32.—Edinburgh (*Solid Edition*).
Sheet 67.—Stonehaven.

6 inches to 1 mile (coalfield maps) :—

Ayrshire, 46 N.E., S.E. ; 47 N.W., S.W. ; 50 S.W. ; 52 N.E.
Fifeshire, 32 S.E. ; 35 N.W., N.E., (35 S.E. and 36 S.W.) ; 37 N.E., S.E. ; 39 N.W.
Lanarkshire, 3 S.E. (*New Edition*) ; 19 N.W. ; 32 S.W., S.E. ; 38 N.W.
Stirlingshire, 18 S.E.

II.—Vertical Sections of Strata

English Vertical Sections published in 1928

Sheet 81.—Sections of Shafts in the Steam Coal Series in the 1-inch map Sheet 232 (parts of Monmouthshire and Glamorganshire). Scale 100 feet to an inch. (*Reprinted.*)
Sheet 84.—Sections of Shafts below the Pennant Grit in the Rhondda Fawr and in the Upper Measures at Llantwit. Scale 100 feet to an inch. (*Reprinted.*)

Scottish Vertical Sections published in 1928

Sheet 14.—Vertical Sections illustrating the Central Coalfield. Limestone Coal Group, Lower Limestone Group and part of Calciferous Sandstone Series in Areas IV and VIII. Paisley, Giffnock, and East Kilbride.

English Vertical Sections in the press at the close of 1928

Sheet 83.—Sections of Shafts in and below the Pennant Grit in the Taff, Aberdare and Rhondda Fach Valleys. Scale 100 feet to an inch. (*Reprinting.*)
Sheet 85.—Sections of Shafts, etc., in the Tawe, Dulais, Neath, Avan, Llynfi, Garw and Ogmore Valleys. Scale 100 feet to an inch. (*Reprinting.*)
Sheet 93.—Sections of Shafts in the Coal Measures of the Abergavenny District (Sheet No. 232) of the South Wales Coalfield, being supplementary to Vertical Sections, Sheet 81. Compiled by T. Robertson.
Sheet 94.—Sections of Shafts and Borings in the Southern Part of the South Staffordshire Coalfield. By Talbot H. Whitehead.

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III.—Memoirs

The following list shows the memoirs published during the year 1928. The work done on them has been mainly the correction of proofs and preparation of indexes.

English Memoirs published in 1928

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for the year 1927:—
Part I.—With Report of the Geological Survey Board and Report of the Director. 82 pp.; 1 text-figure. 1928. Price 1*s.* 6*d. net.*
Part II.—110 pp.; 4 plates; 21 text-figures. 1928. Price 2*s.* 6*d. net.*

List of Memoirs, Maps, Sections, etc. Published by the Geological Survey of Great Britain and the Museum of Practical Geology to 30th June, 1928. Price 1*s. net.*

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Wells and Springs of Sussex. By F. H. Edmunds, M.A. 262 pp.; 1 plate; 11 text-figures. 1928. Price 5*s. net.*

Wells and Springs of Warwickshire. By L. Richardson, F.R.S.E., F.G.S. 204 pp.; 5 text-figures. 1928. Price 5*s. net.*

The Geology of the Country around Wrexham. (Explanation of one-inch Sheet 121: England and Wales.) By C. B. Wedd, B.A., B. Smith, M.A., Sc.D., and L. J. Wills, M.A., Ph.D. With a contribution by G. W. Lamplugh, F.R.S.
Part II.—Coal Measures and Newer Formations. 237 pp.; 5 plates; 11 text-figures. 1928. Price 5*s. net.*

The Country between Wolverhampton and Oakengates. (Explanation of one-inch Sheet 153: England and Wales.) By T. H. Whitehead, M.Sc., A.R.C.Sc., T. Robertson, B.Sc., Ph.D., R. W. Pocock, M.Sc., and E. E. L. Dixon, B.Sc., A.R.C.Sc. With contributions by T. C. Cantrill, B.Sc., H. Dewey, R. L. Sherlock, D.Sc., A.R.C.Sc., J. Pringle and R. Crookall, Ph.D. 244 pp.; 8 plates; 11 text-figures. 1928. Price 5*s.* 6*d. net.*

The Geology of the Country around Woodbridge, Felixstowe and Orford. (Explanation of one-inch Sheets 208 and 225; England and Wales.) By P. G. H. Boswell, O.B.E., D.Sc., Professor of Geology in the University of Liverpool. 80 pp.; 2 plates; 15 text-figures. 1928. Price 2*s.* 6*d. net.*

The Geology of the Country near Ramsgate and Dover. (Explanation of one-inch Sheets 274 and 290: England and Wales.) By H. J. Osborne White. 98 pp.; 5 plates; 15 text-figures. 1928. Price 2*s.* 9*d. net.*

The Geology of the Country near Hastings and Dungeness. (Explanation of one-inch Sheets 320 and 321: England and Wales.) By H. J. Osborne White. 104 pp.; 6 plates; 14 text-figures. 1928. Price 3*s. net.*

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Scottish Memoirs published in 1928

Summary of Progress.—See p. 29.

The Geology of Arran. (Explanation of Arran District Map, including parts of one-inch Sheets 13 and 21: Scotland). By G. W. Tyrrell, A.R.C. Sc., Ph.D., Lecturer in Geology in the University of Glasgow. 292 pp.; 6 plates; 36 text-figures. 1928. Price 6*s.* 6*d. net.*

English Memoirs in the press at the close of 1928

Attrition Tests of British Road-stones.

Special Reports on the Mineral Resources of Great Britain.—Vol. XXXI.—Ball Clays.

Wells and Springs of Derbyshire.

The Country around Oswestry. (Explanation of one-inch Sheet 137: England and Wales.)

The Geology of the Country around Sudbury (Suffolk). (Explanation of one-inch Sheet 206: England and Wales.)

The Geology of the Country around Aldershot and Guildford. (Explanation of one-inch Sheet 285: England and Wales.)

Scottish Memoir in the press at the close of 1928

The Geology of North Ayrshire. (Explanation of one-inch Sheet 22: Scotland.)

Geophysical Surveying

As was reported in the *Summary of Progress* for last year a field party was engaged at the close of the year in making investigation of the distribution of gravity anomalies in a district about eight miles north-west of Glasgow. This survey was continued in 1928 and the field work was brought to a close in the month of March. The party consisted of Dr. W. F. P. McLintock and Dr. J. Phemister, assisted by three or four of the technical staff who performed the mechanical operations and took part in the field surveying and levelling. This had to be done on a very minute scale in order to provide data for the calculation of the disturbing effect of irregularities in the form of the surface in the neighbourhood of the stations.

The problem investigated was the position, and so far as could be ascertained, the configuration of the old pre-Glacial channel of the River Kelvin. This was known approximately from a series of borings put down many years previously in search of the coals and ironstones that occur in the Carboniferous rocks. The specific gravity of the gravel, sand and other Glacial deposits that fill the old valley was about 1·84 and that of the solid rocks which bound the channel about 2·38, and it was anticipated that this difference was sufficient to give an easily observable effect on the torsion balance. At an early stage in the investigation it was clear that this expectation was fulfilled, as residual gradients up to 45 Eötvös units were observed. On the other hand, the disturbances due to surface configuration were rarely more than 25 Eötvös units, though at a few stations on steeply sloping ground they reached 40 units and over.

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Consequently the nature and even the approximate magnitude of the gravitation anomalies produced by the underlying structures were never in doubt, and the experiment proved so instructive that about 60 stations were ultimately observed in order as far as possible to render the evidence obtainable by these methods complete and definite. The task was to a considerable extent simplified by the local conditions, as the surface was flat in the area which was to be most closely investigated, and as the land was mostly under grass, the difficulties of field work in winter were considerably reduced.

With a short interruption at Christmas this party continued the field work till early in March. When the weather was suitable and the instrument was working smoothly it was usual to complete one station every week-night. Each station requires seven readings, at intervals of about one hour, so that the actual observations require about six hours work under favourable conditions. During the day a very careful and complete survey of the ground around each station was made by means of level and tacheometer. The most onerous part of the work, which is the reduction of the observations and the calculation of the residual effects, remained to be overtaken. Very frequently, however, it was possible to complete a series of preliminary calculations during each 24 hours. In this way the residual gradient at each station was known approximately before the position of the next station was decided on, and the observations made at a new position ; and in practice this proved very convenient, as it ensured that only important stations should be observed, and that any interesting results could be confirmed by a group of subsidiary stations without loss of time and without interrupting the uniform progress of the work.

On the return to headquarters the whole of the observations were calculated afresh and independently by the two geologists in charge and maps were prepared on the scale of twenty-five inches to one mile showing the surface configuration of the ground, the direction and magnitude of the gravitational gradient and the contour-lines of equal anomaly, indicated by the observations.

The results were full of interest as it was proved that the position of the deep valley could be closely defined and that an approximate idea could be formed of its configuration, of the steepness and shape of its lateral slopes, the presence of irregular elevations or humps in the rocky floor, and of branches or tributary valleys. Furthermore, from the observed specific gravities of the sands, clays, gravels and Carboniferous rocks it was possible to calculate the depth of the channel at various places, and where this had already been proved by borings there was a fairly close agreement between the observed and inferred results.

It seems clearly established that in the investigation of problems of this nature the usefulness of torsion balance surveys may be sufficiently great to justify the time and money expended on the work. A preliminary survey carried out without unnecessary

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detail may give much information regarding buried drift-filled channels of which there may be little or no surface indication.

As such problems arise frequently in relation to the construction of canals, reservoirs and tunnels, and in connexion with excavations and foundations, a gravitational survey, followed where necessary by trial borings, promises to give useful results. To some extent also such a survey may form a guide to mining operations, as grave accidents may be occasioned by the unexpected intersection of a deep channel filled by drift, especially where the surface materials are full of water or partake of the nature of a running sand.

Conversely, of course, if the balance can thus detect the presence and approximate distribution of masses of material that have a lower specific gravity than the surrounding rocks it can also detect the presence of heavy bodies in similar circumstances. This was clearly proved in the investigation of the Swynnerton dyke, which was reported in the *Summary of Progress* of last year. This property gives this method its principal economic value in the detection of ore bodies that are denser or of masses of rock salt that are less dense than the strata in which they occur.

The survey of the buried Kelvin valley aroused a good deal of interest among those who study geology, mining and general physics. Dr. Phemister gave a lecture on this subject to the Geological Section of the British Association at its meeting in Glasgow in September, 1928. Lectures on this subject have also been given to the Geological Society of Glasgow and the Royal Astronomical Society, and Dr. McLintock and Dr. Phemister have read a paper giving their results in full detail to the Royal Society of Edinburgh. This paper was in the press at the close of the year and from its treatment of the mathematical problems that arise in the discussion of the observations it is likely to have permanent value as a contribution to the literature of the subject.

Field operations were suspended during the summer months partly because of the pressure of other work and partly because the autumn and winter months are more suitable for this class of investigation. Especially on cultivated land it is of great advantage to work at a season when the crops are off the ground and when there is least damage and interference with agricultural operations. Moreover, the type of balance with which the field party was provided proved to be exceedingly sensitive to changes of temperature and other influences that apparently depend on the height of the sun above the horizon. The instrument is provided with automatic photographic registration impelled by clockwork, and theoretically should work equally well by day or by night and should require almost no personal attention. In practice, however, it was found that the beam is seldom steady during daylight, and all observations must be repeated till oscillation has ceased. In the cellars of the Museum in London automatic photographic registration is quite satisfactory; in the field where the action of the wind is often

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strong and where there are rapid changes of temperature, apart from the varying influence of sunshine and shade, it is necessary to observe every precaution if much time is not to be lost. Consequently the observers have, after repeated trial, decided to depend only on visual observations made after sunset and before sunrise. As at least six hours are needed for the observations at each station it is an advantage to do the field work at those periods of the year when the nights are long; even in these circumstances, however, the presence of a strong wind or the rapid fall of temperature due to a clear frosty night may make some or all of the results unsatisfactory and may necessitate repetition under more favourable conditions.

An experiment was made during the summer to find a means to obviate these difficulties. The balance was erected in the grounds of the National Physical Laboratory at Teddington and a special canvas tent, of bell shape, was placed around it to provide shade and shelter from the wind. The observations made in this way were better than with the instrument surrounded only by the metal tent that is provided with the apparatus, but they were not completely satisfactory and for this and other reasons the further prosecution of gravitational surveys was postponed till near the close of the year.

Another factor which must be kept in mind is that the mere calculation of the results involves more expenditure of time than the actual operations in the field, and consequently, if the two sets of proceedings can be carried on concurrently, there is no actual waste of time by accumulating observations under favourable circumstances at such a rate that reliable preliminary results can be attained day by day during the progress of the field work.

It was decided to undertake another programme of geophysical work during the autumn season and the problem selected was one involving geological structure or tectonics. The operations of the Anglo-Persian Oil Company in Persia have proved that the torsion balance can under suitable conditions detect the presence of an anticlinal fold (*Summary of Progress* for 1926, Appendix XII, pp. 168-196; see also *Monthly Notices Roy. Astron. Soc., Geophys. Supplement*, Vol. II, No. 1, 1928). As a further test it was proposed to investigate some well marked fault or fracture line, bringing together rocks of different age and differing not too widely in composition and in specific gravity. After careful inspection a site was chosen in the neighbourhood of Portobello, about three miles east of Edinburgh. The rocks of the Midlothian coalfield which lie in a great syncline are faulted against Carboniferous rocks belonging to a lower horizon by a great fault which is well known to local mining engineers and runs out to sea east of Portobello. The position of this fault is known with sufficient definiteness though the fault is not actually exposed, and on inspection it proved that parts of the country traversed were sufficiently level to make a gravitational survey practicable. Moreover, there was no reason to suspect the presence of irregular rock surfaces or buried channels beneath

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the superficial deposits which everywhere in the district overlie the Carboniferous rocks. Permission was readily obtained from the farmers who cultivate the land; and we are indebted to them for granting every facility for the work. The balance after a thorough overhaul in London was sent to Scotland about the middle of October and within a few days after it had been erected on the ground it was found to be sufficiently steady to enable observations to be started.

As the position and direction of the line of fault were approximately known the first proceeding was to establish a line of stations perpendicular to the line of fault and crossing its probable course. This was accomplished in a few days and it was found that while the gradients were nearly constant in direction they varied greatly in amount. At a place about 200 yards from the line marked on the six-inch geological map as the conjectural position of the fault the gradients rapidly increased in a westward direction. When their magnitudes were plotted against the distances between the observed stations the resulting curve was in striking accordance with the theoretical curve for a fault bringing into juxtaposition two rock masses of strikingly dissimilar density. As a matter of fact the magnitude of the gradients was unexpectedly large, some of them being as high as 85 Eötvös units. Consequently there seemed no room for doubt that the balance had detected the presence of an important geological structure below the covering of drift and alluvial deposits. This covering, it may be remarked, is believed to be from 60 to 100 feet thick, but its thickness is not known, as there are no borings and no natural exposures sufficient to give reliable evidence on this point.

In order to obtain as much information as possible about this interesting line a set of stations was observed, about 25 in number, along a distance of rather more than half a mile. Preliminary calculations and reduction of the observations yielded a graph of very characteristic form but at the same time presenting certain irregularities that invited further discussion.

It seemed obviously desirable to check or confirm these results by observations along other lines parallel to the one first selected. For this purpose two other lines were surveyed to the south-west of the first one and several hundred yards distant from it. The surface being nearly level was well suited for the purpose and the 'terrain' corrections due to irregularity of the ground were in no case very troublesome. The second and third lines of survey amply confirmed the results of the first but each of them showed minor peculiarities of a highly interesting character. In spite of rather inclement weather the field work was practically finished by the end of the year, and the surveyors returned to the office, where all the calculations were repeated and the observations corrected and reduced.

A special report is now being prepared on the results of this geophysical survey, and until that report is completed it is premature

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to enter into detailed discussion or to formulate conclusions. It may be pointed out, however, that the high gradients observed near the fault line may be explained if the rocks on the west side are much more dense than those on the east of that line. Now on the west the Lower Carboniferous rocks are near the surface and in that series occur the well-known lavas of Arthur's Seat. From all the evidence obtainable from surface exposures these lavas were believed to lie at a considerable depth, covered over by shales and sandstones. There is no way of proving the actual facts except by means of a bore, but it seems quite probable that the lavas are not so deeply buried as was conjectured. If the lavas are at or near the surface the problem is similar to that which was previously investigated at Swynnerton, where a basalt dyke is in contact with Triassic marls and sandstone. The gravitational survey at any rate has raised an interesting problem on which light may be thrown at some future date.

As regards the irregularities presented by the graph of gravitational anomalies in the immediate vicinity of the fault line, there is more than one explanation that may prove applicable. This is an important fault having a large displacement, and in such cases it is not unusual to find a belt of broken rocks many yards in breadth in place of a sharply cut fault fracture. This would occasion a sensible alteration in the gradients as the fault belt was crossed and might even in imaginable circumstances cause a local reversal of the gradient if the mass of rock which lies between the boundaries of the fault zone was of very different character from the other rocks in the neighbourhood.

Among the numerous possible explanations for irregularity in the gradients it may also be kept in mind that the fault may split into two or more branches which may diverge for a space and then come together again enclosing a mass belonging to a different horizon and of different physical properties.

Again it is conceivable that as the whole district has been intensely glaciated the broken rock in the fault line may have been eroded into a trough which was subsequently filled with loose surface materials. In this case there would be a buried channel which, if it was sufficiently pronounced, would certainly have an influence on the gravitational gradients.

Discussion of these matters may, however, be left over till the observations have been reduced and reported on. It is sufficient for the present to point out that in this instance as in the previous ones the Eötvös balance has not failed to detect the geological structure which was previously known to exist in the ground examined, and under the circumstances in which it has been employed has proved to be a scientific instrument capable in skilled hands of yielding results not only of theoretical interest but also of practical value. Our programmes of work accordingly may be regarded as successful, as they have always accomplished at least

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as much as was anticipated when they were planned. These new methods of investigation have received very careful study and trial in the field, and a staff has been trained to carry them out in a thoroughly efficient manner.

In last year's *Summary of Progress* it was mentioned that an Australian scientist had received theoretical and practical training in work with the Eötvös balance under Dr. McLintock and Dr. Phemister. Since that date work has been started in Australia on the same lines as in Britain, and an extensive programme of geophysical survey is contemplated.

During 1928 the Research Council of Canada sent over Mr. A. H. Miller to study methods of geophysical observation and survey in Europe, and on the invitation of the Director of the Geological Survey of Great Britain he joined our geophysical unit and worked with them for a time. After some weeks spent practising with the balance in London he proceeded to Scotland and took part in all the field work and the calculations, obtaining a full practical knowledge of the methods which we employ and giving valuable assistance and information to our geologists. It is understood that a programme of field survey with the Eötvös balance may be undertaken in Canada on his return.

Having made several successful researches with the gravitational balance it seemed desirable to try the other instruments which are used for geophysical surveys. After full discussion and consideration it seemed most likely that magnetic surveys would yield useful results with the time and staff at our disposal. There are many problems in Britain on which magnetic surveys may be expected to throw light, and not much of that kind of work has been done, though in 1919 Dr. Walker and Professor Cox published a valuable series of observations on magnetic variation in relation to geological structure.[1] Their conclusions encourage further research, though it is clear that this method, like the others, is specially adapted for the solution of a certain class of problems and cannot be universally applicable. At the close of the year orders had been placed for a vertical and a horizontal magnetometer of standard pattern. As soon as the instruments are received and have been tested a course of magnetic surveys will be taken in hand. Assistance has been promised by the Research Officer of the Ordnance Survey, who is at present engaged in a revision of the magnetic map of Great Britain. It is quite clear that magnetic surveys will be very useful to confirm and extend the results of some of the gravitational surveys that we have already executed. For example the Swynnerton dyke will probably be as easily detected by the magnetometer as by the torsion balance. As soon as possible in the coming year these matters will be put to the test and the results will be as freely published as those of the gravitational surveys have been.

[1] *Phil. Trans. Roy. Soc.*, Series A., vol. 219, 1919.

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Soil Mapping

The attempts which have been made during the last three years to secure active collaboration between the field surveyors of the Geological Survey and the soil experts of Agricultural Colleges who are engaged in testing and classifying the soils of their districts have been continued during the past year and notable results have been achieved. The best methods of classifying soils for the purposes of mapping are not yet agreed upon, and at the present stage every opportunity should be taken of bringing geologists and agriculturists together to the study of some important problem in the field. With this object in view the Development Commission and the Ministry of Agriculture and Fisheries again arranged for a joint visit of geologists and agriculturists to a selected locality to secure discussion and collaboration. This year's conference was held at Oxford in September.

Mr. Howe reports that the Survey was represented by Messrs. T. Eastwood, F. H. Edmunds and J. B. Simpson. The programme before the conference was the study of methods of soil mapping in an area of forest land, the selected site being part of Bagley Wood, near Oxford.

The chosen area is one of moderate relief in which the following geological succession occurs from the higher ground to the lower :— Plateau Gravel, Kimmeridge Clay, Coral Rag, Calcareous Grit and Oxford Clay.

In the opinion of Mr. R. Bourne, of the Imperial Forestry Institute, Oxford, the area was probably originally covered by scrub oak, but about 30 years ago parts had been planted with various kinds of timber in quarter acre plots.

The field party worked in sections, each of which produced a map of its portion of the ground ; these were then compared and studied jointly. Small augers were employed for examination of the subsoil, and attention was particularly directed to the question of podsolization. Certain analyses were to be made to throw light on the degree of podsolizing in a typical profile in the Plateau Gravels, and others to determine the correct texture of some of the soils. The results of these analyses have not yet been received.

In regions such as the one under investigation it would appear that the geological drift map on the six-inch scale is a sufficiently close approximation to the representation of the soil distribution, from the point of view of soil origin. The chief difference between the geological map and the soil surveyors' maps, in this case, lay in the fuller representation of down-wash effects on the latter ; though the presence of such feather-edge deposits and down-washes should be fairly obvious from the geological map, when the outcrops and relief forms are considered in relation to one another. Notes are now being made by the geological surveyors upon maps of areas under survey, which should go a long way towards meeting the requirements of the soil surveyors.

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As regards the progress of soil surveying in Scotland during the past year Mr. Macgregor has sent in the following report :—

Reference was made in the *Summary of Progress* for 1927[1] to the work undertaken by the late Professor R. A. Berry and by his assistants in the Chemistry Department of the West of Scotland Agricultural College on the soils of the Kilmarnock area (Sheet 22, Scotland). The ' soil texture ' map which they had prepared is in course of publication, and three editions of Sheet 22 will thus be available, one showing the ' solid ' geology, another showing the distribution of the superficial deposits, such as boulder-clay, sand and gravel, etc., and a third showing that of the soils classified according to textural differences. It will thus be possible by means of these maps to study the relationships of the various soil texture groups to the underlying ' drift ' and 'solid ' formations. The account of the soils and agriculture of the same area which Professor Berry and his assistants undertook to prepare was completed early in the year, and will form a very useful contribution to the memoir on Sheet 22 ('Geology of North Ayrshire '), now in the press. In this account the soil texture groups—light sands, heavy sands, moderately light loams, moderately heavy loams, heavy loams, and clays—are dealt with in succession, and their distribution, properties and agricultural characteristics described. In each case the nature of the underlying ' drift ' and ' solid ' formations is indicated, and introductory sections to the detailed account deal with ' Topography and Climate,' ' Methods of Research,' ' Soil Classification ' and ' Relation of Soils to Geology.' Tables of mechanical analyses are included and the illustrations comprise a simplified topographical map showing the distribution of the texture groups by means of ornament, a rainfall map of the area, and a number of mechanical composition curves. It should be stressed that mapping and classification of the soils are based on a single factor, that of texture. Owing to the size of the area (390 square miles) and the limited time available, a detailed survey of soil profiles was out of the question. The soils were examined by means of an auger to a depth of 30 in., and, where natural or artificial cuttings could be found, to as great a depth as possible. Field tests of acidity were carried out, and observations made of colour, stoniness, drainage, water table, contour of ground, soil profile, quality of pasturage and crops, etc., while as much information as possible was obtained from County Organisers and from farmers regarding rotations, manures, cropping and stocking powers of the land and rentals.

It is much to be regretted that Professor Berry died before the manuscript was finally ready for the press. He took the greatest possible interest in soil surveying work, and welcomed wholeheartedly the idea of close co-operation between the Agricultural Colleges and the Geological Survey. His death is a great loss to

[1] *Mem. Geol. Surv.*, Pt. I, 1928, p. 22.

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Agricultural Science. Acknowledgment should be made of the assistance rendered by his successor, Professor D. N. M'Arthur, D.Sc., F.I.C., in carrying out certain modifications in Professor Berry's manuscript which were required to bring it into conformity with the rest of the memoir of which it forms part.

In continuation of the work in North Ayrshire Professor Berry and his staff had agreed to undertake a similar examination of the soils of South Ayrshire, and a considerable area in the south-west of Sheet 14 was surveyed during the past summer. Laboratory tests of the soil samples so far collected are at present proceeding in the West of Scotland Agricultural College, and the work, it is hoped, will be continued during 1929 under the supervision of Professor M'Arthur.

Inspection of Bores and Shafts

Every opportunity has been taken of collecting new information under the facilities granted by the Mining Industry Act (1926) from borings and sinkings in progress in mining districts. Probably on account of the depression in the coal trade during the past year the amount of boring has not been so great as might have been anticipated, but two officers of the Survey, Mr. Templeman in England and Mr. Manson in Scotland, have been fully employed visiting borings and shafts, obtaining records of the strata passed through, and collecting specimens of rocks and fossils. The bore journals are very carefully checked and compared with the cores which have come out of the bore. The specimens are registered and added to our rock and fossil collections after they have been determined by our geologists and palaeontologists. In Scotland many of the bore records are drawn up in graphic form, which renders them immediately useful for direct comparison with similar graphic journals of bores from other districts. The exact site of each bore is a matter of considerable importance, especially in districts where there is a good deal of faulting; this is ascertained very carefully and in addition to being recorded on the written copy of the bore journal is marked on the six-inch working copies or bore maps in the collections of the Geological Survey so as to avoid all ambiguity in the future. The bore records are kept in a series of files according to counties and six-inch quarter-sheets. The number of borings varies greatly in different coalfields; some Scottish quarter-sheets covering six square miles have between 200 and 300 bores marked on them. Many of these borings have little geological interest, having been put down only for practical purposes such as to ascertain the depth, thickness and condition of a coal seam well known to occur in that locality. All the deeper or exploratory borings, however, are of great importance to the geologist as often no other information is to hand regarding the sequence and structure in that part of a coalfield and a well executed boring gives very exact and complete particulars regarding all the strata through which it passes.

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Compulsory notification of mineral bores exceeding 100 feet in depth has now been provided, but similar conditions do not apply to borings in search of water. In the South and East of England many deep wells are sunk every year; most of the principal firms engaged in this work are in close contact with the Survey geologists, whom they consult frequently as to the depth of water-bearing strata and the chances of obtaining satisfactory supplies of water. These firms generally supply us freely with information regarding the wells which they make, whether successful or not. The amount of information on this subject increases every year, and a vast amount of it has been published in the Water Supply Memoirs which are well known to engineers and borers in all parts of the country. Wherever these borings are likely to throw light on the stratigraphical succession and structure of the country they are visited by members of the staff, who check the bore records and collect rocks and fossils. It is probable, however, that a certain number of these bores escape notice at the time when they are made and thus it becomes impossible to obtain full particulars regarding the characters of the rocks penetrated and to clear up doubtful points in the records. The Geological Survey is greatly indebted to the kindness of those firms who supply information regarding borings in progress and no effort is omitted to obtain reliable and complete records during the course of the work.

Mr. Howe reports that the number of new borings and shaft sinkings notified in England during 1928 was 9. At the beginning of the year 44 borings that had been notified were still in progress, of which 19 have been completed and 4 have been temporarily suspended. Mr. Templeman has visited 41 boreholes, obtained 51 bore records and collected 726 specimens from borings and shafts. Many visits have also been paid to borings by geologists in search of information regarding the geology of various districts in England. The rest of Mr. Templeman's time has been occupied in arranging the sets of boring records in the London office.

Mr. M. Macgregor reports that in Scotland notification was received of 24 borings and sinkings during the year and several of these included two or more bores or shafts. Not only have the journals been obtained and checked but the preparation of graphic sections has also in practically all cases been carried out. Among the more interesting points which emerge from the boring information obtained in Scotland during the year the following may be noted:—

In a shaft sunk at Mauchline (No. 4 Pit, Mauchline Collieries) the Tourha' Coal was met with at a depth of 36 fathoms 4 feet, and on driving a heading in this seam near the bottom of the shaft the coal was found to pass laterally into a dark grey argillaceous limestone, 1 foot in thickness. Specimens tipped at the surface and examined by Mr. Manson showed that the limestone consists of a

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central granular portion, 4 inches thick, overlain and underlain by an equal thickness of limestone with well developed cone-in-cone structure.[1]

A boring at Kerse, near Patna, proved the occurrence of Skipsey's Marine Band at a depth of 73 fathoms, while 11 fathoms lower a burnt coal overlain by 2 feet of blaes (shales) containing *Lingula squamiformis* represents the position of the well-known Craigmark Ironstone.

A boring near Wishaw (at Garriongill Colliery) and a sinking at Kingshill Colliery, Auchterhead Muir, provide interesting evidence of the extension into these localities of the unconformity near the base of the Millstone Grit Series which has been shown by Mr. C. H. Dinham to be present throughout the Stonehouse-Larkhall-Dalserf district.[2] The Garriongill Colliery bore indicates that here the thickness of the Millstone Grit is reduced to about 20 fathoms, mainly of sandstone, unconformably overlying strata referable to the upper part of the Upper Limestone Group.

The marine horizon which occurs in the Black Metals of the Central Coalfield, near the middle of the Limestone Coal Group, has been recorded in the cores of a blind boring at Foulshiels on the east side of the Lanarkshire basin. An interesting suite of marine fossils was obtained by Mr. Manson from the roof of a coal in the lower part of the Limestone Coal Group in a boring near Blair Mine, Oakley, in Fife. By means of these fossils it is possible to correlate the coal in question with the Smithy Coal of Bo'ness, from the roof of which Mr. H. M. Cadell, many years ago, obtained a very similar assemblage.[3]

Conferences

The first Conference of the Surveyors General of Dominions and Colonies, convened by the Secretary of State for the Colonies, was held in London and Southampton between July 2nd and 13th. An officer of the Geological Survey was in close touch with the Conference throughout the proceedings, and there can be no doubt as to its great value as a means whereby expert experience from all parts of the Empire could be brought to bear upon problems common to all.

Naturally the Conference was concerned mainly with questions connected with trigonometrical and topographical surveys, but such papers as that given by Lieut-Colonel M. N. Macleod on 'Some Problems of Revision' and that on 'Lettering on Maps' by Captain J. G. Withycombe were of considerable interest to the makers of geological maps and gave rise to helpful discussions. At the

[1] *Cf.* Strahan, A., 'On the Passage of a Seam of Coal into a Seam of Dolomite,' *Quart. Journ. Geol. Soc.*, vol. lvii, 1901, p. 297.

[2] Dinham, C. H., in 'Econ. Geol. Central Coalfield, Area IX' (*Mem. Geol. Surv.*), 1921, pp. 76-79.

[3] Cadell, H. M., 'The Fossiliferous Rocks of Borrowstounness Coal-field,' *Trans. Edin. Geol. Soc.*, vol. iv, part iii, 1883, pp. 319-337.

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request of Colonel F. S. Winterbotham a meeting was held in the Museum of Practical Geology on July 7th, when an address was given by Mr. J. Allen Howe on the work of geological surveys and their relation to topographical surveys, a summary of which was circulated to members of the Conference. A large exhibit of geological maps was arranged in the Museum to illustrate types of maps and methods of treatment, with examples from all parts of the world. At the close of the meeting Dr. W. F. P. McLintock demonstrated the Eötvös Balance to a number of members who were interested in geophysical methods.

In June an International Meeting of geologists was held in Copenhagen in celebration of the 40th anniversary of the Geological Survey of Denmark. Practically every country of Europe sent representatives to this meeting. The Director attended as representative of Great Britain and had an opportunity of visiting some of the most instructive exposures and discussing the methods of mapping and the problems of Danish geology with members of the Danish Geological Survey.

At the meeting of the British Association, held in Glasgow in September, the Geological Section (Section C) met under the presidency of Mr. E. B. Bailey, M.C., B.A., of the Scottish Survey staff. By kind permission of the authorities of Glasgow University a room, in close proximity to the lecture hall assigned to Section C, was set aside for the purpose of an exhibition of Geological Survey maps, sections, memoirs, photographs, and drawings. The material exhibited included a number of recently-issued one-inch Scottish maps. Some of the revised maps of Carboniferous areas on the scale of six inches to a mile were also exhibited as well as examples of the Sheets of Comparative Vertical Sections which have been published in recent years to illustrate the sequence in the coalfields of West and Central Scotland. The meeting was well supported by members of the Geological Survey of Scotland, several of whom read papers and contributed to the discussions.

Staff Changes

The Survey has experienced a severe loss by the death of Dr. Gabriel Warton Lee, who joined the staff in 1907 and was well known for his work on Scottish palaeontology. Dr. Lee had not been in robust health for some time, but his death was sudden and unexpected. Educated at Geneva, he had specialised on the fossils of the Scottish Mesozoic and his contributions to the Survey memoirs on Raasay (1920), Mull (1925), and Golspie (1925) will prove of lasting value, but he had also an exceptionally good all-round knowledge of his subject and for many years he did practically all the Carboniferous palaeontology that was required by the work of the surveyors in Scotland. He is the author of a monograph on the Trepostomata in our series of Palaeontological Memoirs. During

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the early years of his service on the staff he did very useful work in the field in the island of Mull and other localities in the West of Scotland. As a museum officer he had exceptional qualifications and the fine series of fossils exhibited in the Survey gallery of the Royal Scottish Museum owes much to his judicious selection and authoritative determination.

Mr. E. M. Anderson, Senior Geologist, belonging to the Scottish staff, has been retired from the service owing to prolonged ill-health.

In September, after a selection by the Civil Service Commissioners, two geologists were appointed to the staff, viz., Dr. C. J. Stubblefield and Mr. W. Q. Kennedy. Of these the former has been assigned to work in England, while Mr. Kennedy has joined the Scottish staff.

Office Accommodation in Edinburgh and Manchester

The transfer of the Scottish headquarters from George Square and George IV Bridge to Southpark, 19, Grange Terrace, Edinburgh, was effected during the month of May and required about three weeks. In spite of the dislocation of ordinary work during this time it was possible to carry on the usual programme without serious interruption. The new offices are situated in a large and roomy house around which there is space for further buildings when these are required. Before the removal the Office of Works installed central heating and electric lighting and made a number of necessary repairs to the structure and roofs. It has been found, however, that the storage space is less than was anticipated and the library and collections are excessively congested and require room for expansion. Many of the rock specimens have to be stored in parcels in an underground cellar which is not suitable for this purpose, and the library is so filled with bookcases that there is not sufficient space for tables on which maps and sections can be spread out. It is very desirable to have a room in which the public who wish to consult manuscript maps can do so in comfort, for many of these maps cannot be seen except in the Edinburgh office. Requests were consequently put forward for the provision of a storage-building in which rocks and fossils could be permanently placed. This would greatly increase the working space and accelerate the work. Draft plans of such a building have been prepared and it is hoped that ultimately, if not immediately, a convenient and well lighted storage-building will be erected in close proximity to the offices in order to accommodate the ever-growing reference collections.

In March, 1928, the Manchester branch office was transferred from 21, Albion Street, Gaythorn, to 270, Oxford Road. The staff in Manchester comprises one district geologist, three geologists and a draughtsman, and their work is entirely directed to the preparation of new maps of the Lancashire coalfield. The new quarters have proved reasonably suitable and have the advantage of being

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very near the Museum and the University. The building in which this office is situated is occupied jointly by the Geological Survey and the Ministry of Pensions.

Collaboration

The Survey continues to receive most valuable support from professional and amateur geologists of eminence. Professor P. G. H. Boswell, of Liverpool University, has had in hand the proofs of two memoirs, one on Woodbridge, Felixstowe and Orford, and one on Sudbury. He has also given assistance in several questions of sedimentary petrology. Mr. E. S. Cobbold has undertaken the study and description of the Cambrian fossils from a district in Shropshire that has been mapped by Mr. Pocock. Dr. Gertrude Elles, of Newnham College, continues to name all graptolites which are collected by the Survey, and her authority on this subject is unquestioned. Mr. L. Richardson has contributed the manuscript of a Water-Supply Memoir on Leicestershire, in addition to revising proofs of his memoirs on Somerset and Warwickshire, and the typescript of memoirs on Worcestershire and Gloucestershire. Dr. G. W. Tyrrell, of Glasgow University, has passed his memoir on Arran through the press, and Dr. R. Campbell, of Edinburgh University, has prepared a new edition of the Stonehaven Sheet (67), and is writing notes for a corresponding memoir. Miss Muir-Wood and Professor O. T. Jones have assisted in the final corrections of their memoirs on *Productus* and *Plectambonites*, which were published during the year. Mr. Hemingway has contributed some very useful information on Carboniferous fossil plants, and Dr. A. E. Trueman has given an authoritative opinion on species of Carboniferous mollusca. Mr. E. J. Lovegrove has given every assistance in the preparation of the handbook to British Roadstones. The Old Red fossil fishes that are being collected in the Orkneys are being determined by Professor D. M. S. Watson, of University College, London, while the fossil plants are investigated by Professor W. H. Lang, of Manchester University. Mr. S. S. Buckman has again acted as specialist on Jurassic cephalopoda, while Dr. L. F. Spath has also contributed notes on other fossils of that group. In the determination of Carboniferous corals we have again had the assistance of Dr. Stanley Smith, of Bristol University, and Professor Hawkins, of Reading University, has investigated Cretaceous echinoids. Mr. W. S. Bisat continues to determine for us specimens of Carboniferous goniatites which are proving to be of much value for zonal correlation in our work in the Lancashire and Yorkshire coalfields.

Mr. Osborne White has completed the manuscript of a memoir on the Saffron Walden Sheet (205), but publication will not be undertaken till the maps of that district receive the necessary revision, as they are in some respects not up to modern standard.

To these and to many others who have proffered information and advice on topics of British geology the Survey is deeply indebted.

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It is with great regret that we record the death of three eminent scientists who have done much to support the Geological Survey in their respective fields of research. Dr. John Horne died in May, 1928, and till within a few days of his death he was engaged in correcting manuscript copies of some of the maps which he and Dr. B. N. Peach had revised in the South of Scotland many years ago. From his wide experience, his great knowledge and his deep sympathies he had been the most valued counsellor and supporter of the Geological Survey of Scotland ever since his retirement in 1911. The whole of the memoirs and maps that Dr. Peach and he had worked on in Scotland during their long periods of service have now been published or prepared in standard form for reference, signed by the authors, and deposited in the Edinburgh office for public use. This makes an immense contribution to Scottish geology, which has never been equalled for variety, for originality and for thoroughness. His death removes from our list of collaborators its most distinguished name.

The death of Sir Aubrey Strahan, Director of the Geological Survey and Museum of Practical Geology from 1914 to 1920, took place at his residence at Fairfield, Goring, Oxfordshire, on March 4th, 1928. Sir Aubrey had served on the Survey for 45 years, having entered as Temporary Assistant Geologist in 1875. He had a special claim for recognition as apart from his distinguished services to geological science he conducted the Survey with great skill and success through the difficult and strenuous years of the Great War, and after peace had been proclaimed he played a prominent part in the reconstruction by which the institution was reorganised on its present footing. Since his retirement he had contributed little to Survey publications but he wrote a short handbook on the Geology of the Thames Valley near Goring as illustrated by the Model in the Museum of Practical Geology (1924); and had never failed to give advice and support when problems of administration were submitted to him.

Professor R. A. Berry, whose death was sudden, had up to the close of his life been actively engaged on field work in Ayrshire, preparing maps showing the distribution of soil types classified mainly according to texture. He combined the most skilled agricultural training with an intense interest in geology; and his work on that subject in Scotland was yielding results of great value and was being closely followed by geologists and by agriculturists.

Palaeontology

ENGLAND AND WALES.—During the year nearly 13,000 specimens of fossils were added to the collections. Apart from the acquisitions by presentation or by purchase, 7,365 specimens have been incorporated in the reference collections and entered in the registers. The number of specimens received by presentation and

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by purchase was 5,612, and of these 3,432 were entered in the registers. The more important of the special sets thus obtained included the following: a collection of 2,300 specimens brought together by the late G. W. Butler, chiefly comprising well collected Cretaceous fossils from localities in Surrey; a collection of more than 1,500 specimens, mostly from the lowest beds of the Chalk in Wiltshire, bequeathed to the Geological Survey by the late Dr. B. Pope Bartlett; a series of 730 specimens (from the collection of the late N. T. Wetherell) presented by Mr. C. W. Hobley, mostly Eocene fossils from localities in the London neighbourhood no longer accessible for collecting; and collections of fossils from the Chalk formed by Mr. A. G. Davis and by Mr. G. W. Young, illustrating their published papers.

Dr. Kitchin has been largely engaged in supervision and editorial duties. Mr. Pringle has studied and named extensive sets of fossils obtained in the areas within a number of sheets in process of being surveyed, while other specimens from these sets and from the Museum have been submitted to specialists who are not members of the staff. The determination of the fossils collected could not be completed within the year, and is still in progress. Mr. Pringle also named the fossils obtained in several borings and drew up lists of the determinations of specimens required in the preparation of a number of sheet memoirs, assisting also by reading the proofs of certain memoirs.

Mr. Pringle paid several visits to the area in the Shrewsbury Sheet, and gave help to Mr. R. W. Pocock in connexion with the Lower Cambrian rocks exposed in trenches made by him at Charlton Hill. He also examined the basement-beds of the Coal Measures at localities between Lilleshall and Little Wenlock, and showed that the rocks at Oldfields Limeworks (near the Wrekin), previously mapped as Coal Measures, are in reality of Lower Carboniferous age. Mr. Pringle paid three visits to shafts in process of sinking at Cefn-coed, near Neath, where numerous fossils were collected from the marine bands passed through there. While in South Wales he devoted some attention to the Millstone Grit, in connexion with the revision of Sheet 230. He also paid a visit to West Cumberland to examine and collect from the Lower Carboniferous rocks at localities near Aspatria.

During the year Mr. Chatwin has been engaged chiefly in work connected with unregistered series of fossils in the collections of the Survey, and with recent acquisitions. Among the more important collections that he named and registered are an extensive series of fossils from the Yorkshire Chalk, from the collection made by the late G. W. Lamplugh; a part of the collection of the late N. T. Wetherell presented by Mr. C. W. Hobley, chiefly Tertiary Mollusca; the collection of fossils from the Chalk of Surrey presented by Mr. G. W. Young; and a zonally important series of fossils from the Upper Chalk of Sussex, presented by Mr. C. T. A. Gaster.

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Mr. Chatwin also examined and arranged the series of Chalk fossils in the collection transferred from the Museum of the Geological Society (preparatory to their registration by Miss M. E. Odell), for the purpose of relegating to a duplicate set the specimens not required for permanent retention. He collated the collection of Eocene, Cretaceous, and Jurassic fossils made by the late Gerard Weedon Butler. He visited Bourton, Dorset, to arrange for the removal of the Pope Bartlett Bequest, and afterwards collated that collection and selected, named, and registered a series from it for the Museum.

The fossil-collecting in connexion with the current Survey work was carried out by Mr. S. W. Hester and Mr. W. Dewar. This entailed visits to the districts in Sheets 152 (Shrewsbury), 166 (Church Stretton), 84 (Wigan), 85 (Manchester), 77 (Huddersfield), 86 (Glossop), 87 (Barnsley), 99 (Chapel-en-le-Frith), 23 (Cockermouth), 231 (Merthyr-Tydfil), 350 (Torquay), and 286 (Reigate). Mr. S. W. Morgan has attended to the registration of Museum specimens, the despatch and return of large numbers of specimens sent out for study, and the increasing duties involved in the miscellaneous work of the office.

Good progress has been made in the registration of specimens. Miss M. E. Odell was engaged for ten months in carrying on that essential work. She continued the registration of the fossils in the large collection formerly in the possession of the Geological Society, and devoted attention also to some of the recent acquisitions.

Numerous enquiries have been answered, and assistance has been given to advanced students and research-workers. More than 2,000 specimens have been sent out to private workers and to specialists for the purpose of study and determination, while 3,771 specimens from the Palaeontological Department were placed temporarily in the hands of other members of the Survey staff; more than 3,400 of these were retained for study in the Manchester Office.

SCOTLAND.—1,718 specimens were added to the collections during the year. These fossils were obtained mainly from the Old Red Sandstone and Carboniferous rocks occupying areas in Sheets 14, 15, 22, 23, 31, 117, 118, 119, 120, and 122. Nearly half of the total collected are fossil fishes and plants from the Old Red Sandstone of Orkney and the Isles of South Ronaldshay, Sanday, and Eday. The Carboniferous fossils were mainly obtained from the cores of borings made in Ayrshire, Lanarkshire, Clackmannanshire, and Fife. The collecting of the material was carried out by Messrs. Tait, Fisher, and Strachan, Mr. Manson dealing with most of the borings.

Apart from the fishes from the Old Red Sandstone, which were submitted to Professor D. M. S. Watson, F.R.S., the examination of the specimens was made by the late Dr. G. W. Lee.

The transfer of the Survey collections to the new offices required a considerable amount of attention; nevertheless, much use has been made of the stored material by workers engaged in the study of special groups of fossils.

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No additions have been made to the exhibited Survey Collection in the Royal Scottish Museum, but there has been some progress in the revision of the naming of specimens shown there.

Palaeobotany

The number of fossil plants added to the collections (by purchase and presentation) during the year was 676. These were chiefly from the Coal Measures in the area covered by the Merthyr Sheet which is now under revision. They have already yielded five new species which have been described by Dr. Crookall. In addition, 20 micro-preparations of various types of coals were purchased from Mr. J. Lomax, of Bolton, and 23 micro-sections of British fossil plants from Mr. W. Hemingway, of Derby.

Loans of specimens for research purposes were made to Professor T. G. Halle, of Stockholm (12 examples of *Lagenospermum*), and to Mr. W. Hemingway (22 specimens of *Rhabdocarpus*).

A considerable amount of time has been spent on current palaeobotanical work in identifying the specimens sent in from the districts at present under survey, and in connection with the palaeobotanical sections for the Ayrshire and Huddersfield Memoirs.

An alphabetical catalogue of the 4,000 photographic negatives in the Kidston Bequest has been prepared.

The Kidston Collection of fossil plants continues to be of considerable use to palaeobotanists, and the following have availed themselves of the collection during the year; Professor A. C. Seward, Dr. D. H. Scott, Professor W. H. Lang, Professor T. G. Halle, Miss E. M. Dix, Mr. W. Hemingway and Mr. W. D. Ware.

In the course of his work, Dr. Crookall has made 5 micro-sections of fossil woods, 16 micro-photographs, 27 photographic negatives, and 282 prints, as well as a number of transfer and maceration preparations.

Petrography

Work in the Petrographical Department has been carried on by the Petrographer, aided by several members of the Geological staff whose field-duties had taken them into regions of igneous rocks. The Petrographer, apart from dealing with many enquiries from the public, Government departments, and officers of the Survey, has been mainly concerned with the petrography of the Tertiary igneous centre of Ardnamurchan. This has entailed the description and review of about a thousand sliced rocks from the region, and a close comparative study of the collections from the neighbouring Scottish Tertiary centres of Mull, Skye, Arran, etc. Mr. E. B. Bailey has been engaged on an examination of the metamorphic rocks and the later igneous intrusions of Coll.

Igneous rocks from the Lleyn Peninsula have been described for Dr. C. A. Matley, and Dr. Thomas, with Mr. W. Anderson, has

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completed the description of the material collected from the Cheviot Hills and surrounding country during the recent re-survey of that district. Dr. Read has continued his work on the igneous and metamorphic rocks of Sutherlandshire, and Mr. A. G. MacGregor has continued his investigations of the lavas and intrusions of Ayrshire, carrying on the work he completed for the Memoir on Sheet 22 (Kilmarnock) into the area of Sheet 14 (Ayr).

Mr. Simpson has published a paper upon the lavas of the Faroë Islands, and Mr. MacGregor presented to the Geological Society of Glasgow an exhaustive paper that dealt with the classification of the Carboniferous basalts of Scotland.

Dr. Tyrrell, of Glasgow, has published as a Survey Memoir his revision of the petrography of Arran, and the volume forms a valuable companion to others dealing with the Tertiary province.

A large amount of interesting material, mainly from dykes, has been collected by the officers recently engaged upon the survey of the Orkney Islands, and the corresponding sections have been dealt with by the Director.

Material from the Shiant Isles has been presented by Dr. F. Walker, who is engaged in a petrographical study of these islands.

The number of sliced rock-specimens and corresponding sections registered in the collections and housed in the Petrographical Department in London is as follows :—

English and Welsh	14,471
Scottish	26,690
Irish	451
Foreign	2,770
Total	44,382

This represents an aggregate increase of 778 in the registered sliced specimens during the past year. Of the corresponding sections 738 were made in the London Office and 40 were registered for preparation in Scotland.

Photography

Mr. J. Rhodes has been employed in taking geological photographs and views, mainly in the districts of Gloucestershire, Devonshire, Northumberland, Lancashire and Yorkshire, to the number of 384.

The number of registered negatives is now as follows :—

English Photographs	4,603
Photomicrographs	1,895
Miscellaneous	1,869

Prints to the number of 1,433 have been made in the London office, chiefly for incorporation in the Survey albums in the London and Scottish offices.

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Mr. Rhodes has mounted 1,058 prints and 816 descriptive forms for use in the English and Scottish Survey Libraries and provincial offices.

The albums are now completed to the following registered numbers, each photograph being accompanied by its corresponding descriptive form :—

English Series	4,219
Scottish Series	3,095

Miss E. M. Lind Hendriks, under the supervision of the Director, has prepared a list of Classified Geological Photographs selected from the Survey albums for the use of lecturers and teachers and as suitable for the illustration of manuals of geology. About 2,500 of the most characteristic views have been chosen from the Survey collection, arranged under descriptive headings, and their localities and geological features have been briefly stated. This work is meant for a handbook to those who wish to consult the albums, which are now so large that it is difficult to search them for the best examples of geological structure and scenery. The book has been well received and numerous applications have reached us for copies both from European countries and from the United States and Canada.

Mr. Robert Lunn, who for many years took all the Scottish photographs for the Geological Survey, has completed a catalogue of our Scottish geological negatives arranged according to the Sheets of the one-inch geological map. This catalogue will be of much use as it enables us to find all the views from any particular district without elaborate search. It gives also particulars of the subject taken and of the quality of the negative. From this catalogue a card-catalogue has been made for the London office. Visitors to the library who wish to see geological views of any part of Scotland can find them easily through this means.

Chemistry

The number of rock-specimens registered in this department's books as analysed or for analysis at the end of 1928 is as follows :—

English	342
Scottish	510
Irish	2
Welsh	55
Others	46
Total	955

Of these, nineteen have been analysed during the year and eight are still in progress of analysis. Thirteen qualitative examinations have been carried out for Survey officers and many enquiries from other sources have received attention.

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Mr. R. Sutcliffe, M.A., A.I.C., was transferred on August 20th, 1928, to the Government Laboratory.

Museum of Practical Geology

In the Museum in London no important changes have been made during the year. No further defects have been discovered in the structure of the building and the temporary electric lighting installation continues in the same state as before. In view of the report of the Royal Commission on National Museums and Galleries and the steps taken last year to press the urgent necessity for a new building it has not seemed worth while to initiate changes of exhibits on any considerable scale. A new display of recently published one-inch maps has been put out in the entrance hall and the most striking accessions to the collections of minerals and gemstones are shown in special cases near the top of the main staircase. A large part of the Museum, however, is so dark that the specimens exhibited cannot be properly inspected unless they are taken out of the cases. The growing collections urgently require more room and everything that can be done to pack them more closely and utilize every cubic foot of space available has been tried. New iron racks of drawers for the fossil cabinets in the palaeontological rooms were being installed at the close of the year, and part of the old chemical laboratory was being adapted for use as a photographic room as required. The temporary roof continues to afford a sufficient protection against the weather though it leaks badly during rain, and the removal of the glass windows renders the interior of the building almost useless for the purpose for which it was constructed.

List of Donations during the year 1928

ADCOCK, C.P., ESQ.—Demantoid, cut and uncut, from Italy.

BRADLEY, R. W., ESQ.—Twelve pictures painted upon mica from India.

BURKE, E., ESQ.—A specimen of *Mantelliceras sp.* from the Chloritic Marl of Ventnor, Isle of Wight (collected during subsidence of July 1928).

COBBE, H. N. C., ESQ.—Telluride ore from Kalgoorlie.

DAVIES, W. J. & SONS, Ltd.—Chloritoid with corundum.

DAVISON, E. H., ESQ.—Veinstone showing wolfram changing to scheelite.

DRUGMAN, DR. J.—Quartz twins selected from material collected by Sir John Flett, K.B.E., F.R.S., etc.

EDMONDS, C., ESQ., J.P., F.G.S. (*per* Dr. B. Smith, M.A., F.G.S.).—A specimen of *Orionastraea ensifer* (Edwards and Haime) from the Carboniferous 4th Limestone (top of Potholes Limestone) of Clints Quarry, near Bigrigg, Cumberland.

FABER, OSCAR, ESQ., O.B.E., D.Sc., M.INST.C.E.—A specimen of *Nautilus* from the London Clay (in excavations for foundations) east of Marconi House, Aldwych, W.C.2.

FRANCK, S. M. & Co.—Artificial lapis beads.

GASTER, C. T. A., ESQ., F.G.S.—A series of specimens, including zonal forms of *Echinocorys*, from the Upper Chalk of Sussex.

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GLASSON, L., Esq.—Large group of selenite crystals from Eden Valley, Cumberland.

GOODCHILD, Dr. W.—Laumontite from Park Brow, Dockwray, Cumberland.

GREENLY, E., Esq., D.Sc., F.G.S.—A series of specimens (seeds and marine shells) from the Pleistocene deposits of North Wales.

GREY, Rev. J. C.—Limonite concretions from Dordogne, France.

GRIFFITH, PERCY, Esq., M.Inst.M.E., M.Inst.C.E., F.G.S.—Two specimens of *Exogyra sinuata* (J. Sowerby), and an associated cluster of *Serpula sp.*, from the Tealby Beds between depths of 43-51 feet in well excavation at Skegness Water Works, Welton, Lincolnshire.

HAYES, Dr. A. C.—Large block of iron ore from Wabana, Newfoundland.

HESTER, S. W., Esq.—A series of specimens from the Upper Chalk (*Hyphantoceras reussianum* subzone) of Aston Hill, near Aston Rowant, Oxfordshire.

HOBLEY, C. W., Esq., C.M.G.—A large series of fossils from the collection of the late N. T. Wetherell, including a series of London Clay shells collected from exposures no longer accessible; also a fine example of *Exogyra sinuata* (J. Sowerby) from the Lower Greensand (Hythe Beds) of Rag Quarry, near Alington Lock, Kent.

HORE, H. H. Esq.—Two specimens of ancient slags from Ewhurst, Sussex.

ICHTHYOL, Messrs, Ltd.—Sample of the oil-shale from which 'Ichthyol' was prepared.

KHASIA SILLIMANITE SYNDICATE Ltd.—see Swetenham, C.C., Esq.

LEACH, A. L., Esq., F.G.S.—A small series of fossils from the Carboniferous Limestone (Upper Seminula Zone, S_2—near top) of Proud Giltar, near Tenby, South Pembrokeshire.

MACARTNEY, Ross, Esq.—Cassiterite and wolfram from Lower Burma.

MACGREGOR, M., Esq., M.A.—Crystallised barytes from Leadhills, Scotland.

MARSH, Miss Joan.—Curiously marked flint from Frinton, Essex.

MATLEY, C.A., Esq., D.Sc., F.G.S.—A series of Ordovician fossils from the Lleyn Peninsula, Carnarvonshire. Eleven rocks and rock-sections from the Lleyn Peninsula. Also suites of rocks, mainly igneous, from the same district of Carnarvonshire.

MOORE, E. W. J., Esq., B.Sc., A.I.C.—Specimens of *Dimorphoceras discrepans* (T. Brown), *Dimorphoceras gilbertsoni* (Phillips) and *Goniatites crenistria* Phillips, from the Bowland Shales of Pendle; and *Anthracoceras atratus* (Beyrich) from the Lower Coal Measures of Accrington, Lancashire.

NEWTON, E. T., Esq., F.R.S., F.G.S.—A series of shells and fish-teeth from the Basement Bed of the London Clay at Ayot Green, near Welwyn, Hertfordshire, including *Odontaspis elegans* (Agassiz), *Odontaspis cuspidatus* (Agassiz), *Lamna vincenti* (Winkler) and *Phyllodus toliapicus* Agassiz, mentioned in *Proc. Geol. Assoc.*, vol. xix, p. 355, 1906.

PIZZALA, Joseph, Esq.—Gypsum in centre of pyrite nodule.

POPE BARTLETT, Benjamin, Esq., M.R.C.S., The Executors of the late.—The collection of Cretaceous fossils made by the late Dr. B. Pope-Bartlett, comprising about 1,500 specimens.

POPHAM, J. L., Esq.—Specimens from a mining district of Venezuela.

RICHARDSON, L., Esq., F.R.S.E., F.G.S.—A specimen of *Tulophorites* aff. *tulotus* S. Buckman, from the Great Oolite of Salperton, Gloucestershire.

RUSSELL, Arthur, Esq.—Pennine from Chile.

SEDGWICK CLUB, The, *per* W. B. R. King, Esq., O.B.E., M.A., F.G.S.—A series of specimens from the Ordovician, Silurian and Carboniferous rocks of the Oswestry District.

SMITH, Dr. Bernard, M.A., F.G.S.—Barytes from Bigrigg, Cumberland.

STAPLETON-COTTON, Colonel.—Crystals of a chromium-bearing amphibole, from Norway.

STRAKER, E., Esq.—Series of iron slags from Sussex.

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STYRIAN JADE LTD., MESSRS.—Bowl made of Styrian jade.

SWAN, CHARLES, ESQ.—Beryl burnt to resemble aquamarine.

SWETENHAM, C. C., ESQ. (*for* KHASIA SILLIMANITE SYNDICATE LTD.).—Sillimanite from Khasia Hills, Assam.

TULLY, B. J., ESQ., F.G.S.—Specimens of parisite and malachite, also cut specimens of cassiterite, tourmaline, hauyne and a garnet doublet.

WALKER, DR. F.—Additional suite of specimens, 17 in number, from the Shiant Isles.

WHITELEY, J. H., ESQ.—Tested silica bricks.

YOUNG, G. W., ESQ., F.G.S.—A series of specimens from the Chalk area of Western Surrey, illustrative of his paper in *Proc. Geol. Assoc.*, vol. xx, p. 422, 1908.

JOHN S. FLETT,
Director.

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II. DISTRICT REPORTS

(A)—ENGLAND AND WALES

1. SOUTHERN DISTRICT

HENRY DEWEY, District Geologist.
H. G. DINES, A.R.S.M., A.M.INST.C.E.
W. LLOYD, B.Sc.
F. H. EDMUNDS, M.A.
C.J. STUBBLEFIELD, B.Sc., A.R.C.Sc., PH.D., D.I.C.
} Geologists.

In the Southern District the survey of the Reigate map (Sheet 286) was commenced by Messrs. H. G. Dines and F. H. Edmunds. In the autumn Dr. Stubblefield joined the unit and was engaged in mapping a small area near Dorking. In the early spring Mr. F. H. Edmunds surveyed on the six-inch scale an area near Portsdown Hill between Purbrook and Hayling Island, while Mr. Dines completed the revision of the drift and some of the solid formations of the Cotswold Hills between Moreton in Marsh and Cheltenham, for the new one-inch Sheet 217.

Mr. Lloyd has continued the revision of the Torquay district for the new edition of the memoir (Sheet 350).

Mr. H. G. Dines and Dr. Robertson were specially delegated to make a mine survey of the old South Terras Uranium Mine and also of the Tolgarrick Mine, near Grampound Road, Cornwall, on behalf of the Special Committee on Radium Resources. The field work is complete, but no report can be issued until the assay analyses have been made.

Mr. Dewey's time has been mainly occupied with indoor work on editing the following maps and memoirs:—Aldershot (285), Sudbury (206), Dover (290) and Ramsgate (274), Hastings (320) and Dungeness (321), Moreton in Marsh (217), Windsor (269). In addition there has been an increasing number of enquiries relating to water-supply, soils, foundations for buildings and sites for tunnels, and upwards of 300 received attention. Mr. Dewey inspected the field-work of Mr. Edmunds in Hampshire and Surrey, and of Mr. Dines in Gloucestershire and Surrey, and also examined some gravel deposits on the Chilterns and at Bedford. Mr. Edmunds attended the Conference on Soil Surveys with the Ministry of Agriculture's representatives at Oxford.

REIGATE SHEET

Lower Greensand.—Mr. Dines has mapped a strike-fault with the downthrow south to which the outliers of Hythe Beds north-east and north-west of Nutfield Station owe their preservation. The

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maximum amount of throw appears to be at Lyttel Hall, where it is about 40 feet. The fault probably extends as far eastward as Tilburstow Hill.

The Sandgate Beds are only thinly developed at Reigate Park, but they cover more of the dip-slope of the Hythe Beds than is shown on the Old Series map Sheet 8.

The Folkestone Beds present an unusual feature of a bed of clay up to 10 feet thick in their higher parts. It has been noted by Mr. Gossling on the west at Buckland and on the east of Reigate in Apted's pit, north of Wray Common, and was recorded by Topley[1] in the road cutting at Tunnel Hill, Reigate, and north of Reigate Heath, but beyond these limits it has not been traced. At Buckland it is separated from the Gault by about 60 feet of coarse pebbly sand, and is underlain by fine white and yellow sand. At Tunnel Hill the coarse pebbly sand appears to be about 30 feet thick, while at Apted's pit the clay bed crops out immediately south of the Gault. Eastwards of Apted's pit the pebbly sand again underlies the Gault; this rather suggests a small local unconformity in the Folkestone Beds.

The **Gault** and the **Upper Greensand** and **Chalk.**—A dip-fault with the downthrow to the east extends from ½ mile east of Wray Common north-westwards. It dislocates the Gault, Upper Greensand and the Chalk, but the extent of the disturbance in the Chalk cannot be proved until the zones are determined.

Mr. Edmunds has surveyed an area of Gault, Upper Greensand and Chalk around Dorking, where the lower beds are affected by a monoclinal fold with an east to west axis. Between Leatherhead and Epsom the outcrop of Upper Chalk presents no unusual features.

Tertiary Beds.—Mr. Edmunds and Dr. Stubblefield note the occurrence of outliers of the Tertiary Beds consisting of Reading Beds and Thanet Sand near Headley, but only of Thanet Sand at Walton-on-the-Hill and Burgh Heath. The beds form one outlier at Nower Wood, Headley, and not two, as indicated on the old geological map.

Drift Deposits.—A wide tract around Horley has been observed by Mr. Dines to be covered locally with a remarkable deposit of gravel consisting of fragments of shale from the Weald Clay, and more or less cemented with ferruginous matter, set in a matrix of finely comminuted shale. This gravel is known locally as 'chevick.' It averages from 2 to 3 feet, but in some parts attains 8 feet, in thickness. A slightly loamy clay spreads over it to a depth of 2 to 3 feet, and as this clay is indistinguishable in surface exposures from the Weald Clay the boundary is very difficult to trace. The Weald Clay holds up water at the base of the chevick and numerous wells have been dug to obtain small supplies.

[1] 'Geology of the Weald' (*Mem. Geol. Surv.*), 1875, p. 141.

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In the survey of the area around Redhill and Reigate Mr. F. Gossling, a member of the Geologists' Association and of the Weald Research Committee, has rendered great help, and has kindly placed at the disposal of the Survey his detailed notes of temporary sections made during recent years. This information has materially assisted the work of drawing boundary lines, especially in town areas.

In Hampshire Mr. Edmunds records the existence of a wide-spread mass of chalky detritus, briefly described by Mr. H. J. O. White,[1] which marks the lower slopes of the Portsdown Hill and extends thence southwards to below sea-level. He also observed some high-dipping beds exposed in a road-cutting about a mile south of Purbrook, where the London Clay and the Reading Beds dip about 30 degrees north. The narrow outcrop of these beds is due to their high dip and not to abnormal thinness.

Torquay Sheet

Mr. Lloyd has examined numerous temporary trenches in Torquay, Paignton and Totnes, which show that it is impossible to subdivide the Permo-Triassic rocks into a definite sequence of clays, sandstones and conglomerates, for each may laterally replace the other.

Careful search has been made for fossils in the Lower Devonian rocks in order to ascertain if the correlation on broad lines put forward by Dr. Asselbergh,[2] of Belgium, could be substantiated in detail. While it may be safe to assume that the Gedinnien-Siegenien and Emsien are in part represented by the Dartmouth Slates, Meadfoot and Staddon Beds, yet the relative scarcity of fossiliferous horizons and the highly disturbed relations of the beds do not admit of the detailed application of the continental zones.

H. Dewey.

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[1] 'Geology of the Country near Fareham and Havant' (*Mem. Geol. Surv.*), 1913, p. 77.

[2] 'Correlation of the Meadfoot Beds with the Siegenien of the Ardennes,' *Geol. Mag.*, 1921, p. 165.

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2. MIDLANDS DISTRICT

C. H. DINHAM, B.A., District Geologist.
C. B. WEDD, B.A.
R. W. POCOCK, M.Sc.
T. H. WHITEHEAD, M.Sc., A.R.C.Sc.
T. ROBERTSON, B.Sc., PH.D., A.INST.M.M.
} Senior Geologists.

Except for a few points of detail, requiring further investigation, the revision on the six-inch scale of the area included in one-inch Sheet 152 (Shrewsbury) was completed during 1928. Mr. Pocock was working in the Severn Valley, between Cressage and Shrewsbury, including the districts of Pitchford, Condover, Berrington and Atcham. Mr. Whitehead's area lay to the south-west around Pulverbatch and Leebotwood, while Dr. Robertson's was to the south, between Harley and Longnor. A small area east of Westbury was mapped by Mr. Wedd, but for most of the year he was engaged on indoor map-work, and along with Mr. Dinham, on the preparation of memoirs for the press.

Pre-Cambrian.—Mr. Pocock finds that the Uriconian rocks of Charlton Hill, on the line of the Church Stretton fault-complex, consist mainly of ashes and conglomerates. The same rock-types occur at Brom Hill to the south and round Dryton. Uriconian ashes and conglomerates, traversed by basic igneous dykes, are also exposed in the south bank of the River Severn at Cound Lodge Inn, and in the adjoining railway cutting. Similar ashes crop out near Harnage House and in the valley of Cound Moor Brook near Stevenshill, where they are in faulted contact with the Harnage Shale.

Dr. Robertson's examination of the northern end of the Lawley hill, farther south-west, shows that the greater part of the Uriconian there consists of volcanic ashes, with some rhyolitic flows and several intrusions of dolerite. The Uriconian definitely extends for at least half a mile north-eastwards beyond the northern end of the hill. The Western Boundary Fault, which is the northward extension of the Church Stretton Fault, appears to have at least two components.

No attempt has been made to map separately the sub-divisions of the Eastern Longmyndian recognised by J. F. Blake[1] and C. Lapworth,[2] as this part of the sequence is particularly poorly exposed in the area surveyed by Mr. Whitehead. A line of division between the Eastern and Western Longmyndian has, however, been drawn with as much accuracy as the conditions permit. The line adopted corresponds with the 'base' (or eastern limit) of the Haughmond conglomerate, where this bed can be recognised. This is the easternmost of the three conglomerates distinguished by

[1] *Quart. Journ. Geol. Soc.*; vol. xlvi, 1890, p. 386.
[2] In 'Geology in the Field,' *Geol. Assoc.* Jubilee vol., 1910, p.746.

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Lapworth in the Bayston Group of the Western Longmyndian. On Smethcott Common and near the Betchcott (Batchcott) Hills, however, only two conglomerates have been found, and it appears that the Haughmond conglomerate must die out at some point north of the former locality. The peculiar micaceous grits associated with this conglomerate on Haughmond and Sharpstone Hills can, however, be recognised where the conglomerate itself appears to be absent. These grits are separated fairly sharply from the more shaly beds to the east of them, which have been relegated to the Eastern Longmyndian. Although some of the rocks to the east of it show affinities with the Western Longmyndian, the line of division chosen is the most practicable for the purposes of mapping, and it appears to correspond with that adopted by Lapworth.

The Western Longmyndian falls into three well-marked sub-groups to which the following names (in order from east to west) may provisionally be given :—

Bayston Group,[1] purple grits with conglomerates.

Bridges Group,[2] dark purple sandy shales with relatively fine-grained grits.

Oakswood Group,[3] red-purple grits with conglomerates.

The approximate limits of these sub-groups have been drawn on the map.

The Longmyndian rocks of Sharpstone Hill, south of Shrewsbury, continue north-eastwards, into Mr. Pocock's ground, the divisions observed by Mr. Whitehead at Bayston and Lyth Hills. The Haughmond, Darnford and Stanbach conglomerates of the Bayston Group are well developed, and in Sharpstone Quarry there is a fine exposure of the purple and green grits that lie between the first two of these.

South-east of Sutton Hall purple and grey flaggy shales are exposed in a small pit just east of the outcrop of the Haughmond conglomerate and, about 150 yards east of this pit, an exposure shows lavender sandstone and marl of Keele Beds type. The junction between the Keele and Longmyndian appears to be a fault. An exposure of grey Longmyndian flaggy shale with calcareous bands, about 100 yards in length, was found in the right bank of the River Severn on the line of this fault; this outcrop forms an interesting link between the Longmyndian rocks of Sharpstone Hill and those of Haughmond Hill.

The Longmyndian inlier at Pitchford has also been mapped. The rocks exposed consist of grey-green and purplish flags with some calcareous bands.

Cambrian.—Mr. Pocock has continued his examination of the Cambrian area of Rushton, between the Wrekin and Charlton Hill.

[1] Lapworth, C., *loc. cit.*

[2] From 'the Bridges' near Ratlinghope (Sheet 166).

[3] See 'Summary of Progress' for 1927 (*Mem. Geol. Surv.*), Pt. I, 1928, p. 40.

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Natural exposures are poor and infrequent and much of the ground is obscured by drift while, in addition, the difficulties of mapping are increased by the complex faulting.

The ground has been trenched at critical points, and numerous trial holes have been put down, from which sufficient information has been obtained to formulate a reasonable interpretation of at least a part of the sequence and to make it possible to map the boundaries of Lower, Middle and Upper Cambrian with some approach to accuracy.

A large number of fossils have been collected from various horizons and these are being examined and reported on by Mr. E. S. Cobbold. Until he has completed this work it will not be possible to discuss the sequence in detail. It can be said, however, that the presence, in place, of the several horizons recorded in last year's *Summary of Progress* has been confirmed by the trenching and trial holes.

The Cambrian rocks have been proved to extend round to the west side of Charlton Hill, where they are cut off by the main line of the Church Stretton fault.

Between the Lawley and Hoar Edge, though for the most part concealed under drift, both Lower and Upper Cambrian are definitely present in Dr. Robertson's ground, and it is hoped that further search will enable some subdivision of the latter to be made. The basal quartzite forms much of the western slope of the Lawley, as is also the case on Caradoc and the Wrekin.

Ordovician.—The base of the Ordovician in Dr. Robertson's area is the Hoar Edge Grit. It rests unconformably on the arenaceous beds at the top of the Shineton Shale sequence, and varies in thickness from less than 40 feet above Harnage Grange to 350-400 feet on Hoar Edge. North-east of Shadwell Coppice it is composed chiefly of flaggy calcareous sandstones with abundant fossils, but to the south it thickens rapidly by the introduction of sandy beds in which the calcareous facies practically dies out. The lower portion of the grit at Ruckley is very pebbly, and excellent examples of dreikanter were found in it there. The sand grains are in general rounded.

The Hoar Edge Grit is succeeded by the Harnage Shale, which usually forms low-lying drift-covered country, and is poorly exposed. It is some 1,000 feet in thickness in this area and is followed by the Glyptocrinus Flags and the Chatwall Sandstone, owing to the gradual introduction of more sandy sediment. The Chatwall Sandstone is very glauconitic in the neighbourhood of Chatwall. Towards the top of this sub-division fossiliferous bands appear, first of all with gasteropods, and later with brachiopods, forming the Alternata Limestone. Faulted outliers of all the groups from the Hoar Edge Grit to the Alternata Limestone occur in the Caradoc-Wrekin fault-zone around Acton Burnell and Coundmoor. Above

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the Alternata Limestone at Chatwall lie the Longville Flags, but these last are overstepped by the base of the Silurian south-west of Church Preen, and none of the higher beds of the Caradocian are present in this part of the sheet. An outline of the Caradocian succession in this area has already been given by C. Lapworth.[1]

Ordovician rocks are found also in Mr. Pocock's area, in thickly wooded ground near Harnage and Coundmoor Brook, where the Hoar Edge Grit and Harnage Shale are involved with Shineton Shale and Uriconian strata in a highly complex fault-belt.

Silurian.—Owing to paucity of relevant exposures, the thicknesses of the three local divisions of the Valentian can be estimated only roughly. The name Kenley Grit is suggested by Dr. Robertson for the arenaceous basement beds. An exposure of grey calcareous and sandy beds, associated with fragments of Pentamerus limestone in Bentleyford Brook, north of the Lawley, indicates the presence of the Pentamerus Group just west of the main line of the Church Stretton fault. The line between the Purple Shale Group and the Pentamerus Group has been drawn at the base of the beds actually characterised by the presence of purple and green shales, as this is the most satisfactory lithological horizon. It does not necessarily coincide with any line drawn on palaeontological grounds.[2]

Carboniferous.—The Coal Measures in the area surveyed by Mr. Whitehead are almost entirely concealed by superficial deposits. Some information concerning the collieries at Longden Common, including a plan giving the workings in one of them up to 1880, has been furnished by Mr. S. Fenn. It appears that only one coal was known in this district. The presence of a Spirorbis limestone is indicated by fragments found on one of the pit-banks. Of the Leebotwood Coalfield there is little to add to Murchison's account.[3] The principal pits were at Longnor. Three coals were known, identified with the Yard, Half Yard, and Thin Coals of the Pontesbury field. A Spirorbis limestone is present. One pit is situated about 150 yards east of the railway, some 600 yards south of a cutting in which Longmyndian shale is exposed. Judging from the size of the spoil bank this pit cannot be very shallow, and it would thus seem probable that the junction between the Coal Measures and the Longmyndian is a fault.

At Pitchford, within Mr. Pocock's area, the basement bed of the Coal Measures is composed, in places, of a breccia of Longmyndian shale fragments in a matrix of bituminous sand. Spirorbis limestone and a bed full of fossil wood occur in Row Brook near the base of the measures. Lower down the brook some red marl in the Keele Beds yielded a number of specimens of *Spirorbis*; this appears to be the first record of this fossil from any marl in the Keele Beds.

[1] In 'Summary of Progress' for 1915 (*Mem. Geol. Surv.*), 1916, p. 38.
[2] Whittard, W. F., *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927, p. 737.
[3] 'Silurian System,' 1839, p. 93.

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Dark bituminous Spirorbis limestone was also found, apparently near the base of the Keele Beds, a short distance north of the Longmyndian outcrop in the Severn River bank, north-east of Sharpstone Hill. There appears to be no evidence for the fault shown on the old map as running north-westward through Eaton Mascott between the Trias and Permian (Keele Beds).

An outlier of calcareous conglomerate resting on Keele Beds was found to form a capping to the high ground one mile south-west of Pitchford Hall. This conglomerate appears closely comparable to the Alberbury breccias and conglomerates, some 10 miles to the north-east, and forms an important connecting link with the Enville conglomerates.

Trias.—The outcrop of Pebble Beds, shown on the old map, east of Longnor Hall, near the Severn, should probably be referred to the Lower Mottled Sandstone.

Superficial.—Mr. Whitehead finds that the rather stiff boulder clay of the Habberley Valley and the valleys immediately to the east gives place, around Cothercott, Picklescott and Woolstaston, to lighter and more stony deposits. Around Smethcott and Woolstaston stony clays, clayey gravels and cleaner gravels shade off into one another laterally, but tend to map out as lenticles approximately following the contours of the ground. This suggests that the deposits, as a whole, are stratified, but bedding can seldom be discerned in the few sections available.

The clayey gravels of the Rea valley, referred to in the *Summary of Progress* for 1926,[1] appear to have their counterpart in similar gravels occupying flattish ground south of Bayston Hill. This flattish area is in continuity with a terrace, at about 300 feet above O.D., which between Condover and Stapleton is, on the average, between 30 and 40 feet above the flood plain of the Cound Brook. The tributaries that enter this brook from the west are bordered by areas which from side to side are almost flat, with a very gentle slope apparently graded to the level of the terrace. These flattish areas, though topographically very distinct, are occupied by stony clay and clayey gravel not readily distinguishable from the drifts of higher levels. In some cases the flat areas end, up stream, in a low terrace ; and, in nearly every case, the valley closes in, at a height of about 500 above O.D., to form a steep-sided dingle with a flat bottom.

Moundy drift covers Mr. Pocock's ground round Berrington, Betton and Bomere. Esker-like ridges of sand and gravel form conspicuous features of the landscape, while meres and peat mosses occupy the hollows. The general trend of some of the ridges and hollows appears to be aligned with the gap in the Longmyndian ridge between Sharpstone and Bayston Hills.

[1] *Mem. Geol. Surv.*, 1927, p. 45.

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Strong glacial striae running north and south were observed on the surface of the Longmyndian grits at the top of Sharpstone Quarry, while at Charlton Hill the direction of the striae on the Uriconian rocks is to the south-south-east.

C. H. DINHAM.

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3. YORKSHIRE DISTRICT

Headquarters : York

C. E. N. BROMEHEAD, B.A., District Geologist.
D. A. WRAY, PH.D., M.SC., Senior Geologist.
J. V. STEPHENS, B.SC., B.ENG. } Geologists.
WILFRID EDWARDS, M.A. }

Early in the year Mr. G. V. Wilson left the Yorkshire staff for Scotland on promotion. Mr. Stephens was again lent for work in Orkney for three months. Much of Dr. Wray's time was taken up by work in the Concealed Coalfield taken over from Mr. Wilson. Though the amount of field work has thus been curtailed, the mapping of the area covered by the one-inch map Sheet 86 (Glossop) may now be regarded as complete. Mr. Bromehead and Dr. Wray have been engaged on the Coal Measures in the north-eastern part of the Sheet, Mr. Edwards and, in the later part of the season, Mr. Stephens on the Millstone Grits in the south. The succession of beds below the Kinderscout Grits has been worked out, though exposures of marine bands have not been found.

Now that the one-inch map has been completely surveyed a general view of the Millstone Grit succession becomes possible and local names for the various ' rocks ' (grits, sandstones, flags, etc.) can be selected where necessary. The oldest strata exposed belong to the Shale Grit Series, which is seen to a thickness of 200 to 300 feet. It consists of grit and sandstones with frequent partings of sandy shale ; these beds are exposed in the Saddleworth, Tame and other valleys on the west of the area, in Longdendale and over the high moorland south of Bleaklow (Hill). Separating these beds from the Kinderscout Grits are the Grindslow Shales, usually 300 to 350 feet, though sometimes less where the pebbly base of the Kinderscout Series has ' ravined ' them : they are micaceous shales and mudstones with occasional bands of sandstone and grit. These shales contain a marine band from which fossils were collected long ago by Holroyd and Barnes from an exposure below Raven Stones in the Chew valley.[1] These fossils are preserved in the Manchester Museum and have recently been determined by Mr. J. W. Jackson as *Reticuloceras reticulatum* Bisat, type form. The bed is therefore the same as that found in the corresponding position in Sheet 77 ; unfortunately it is not now exposed, owing to fallen debris, and its exact position in the Grindslow Shales is not known. Farther south it is absent, as in Derbyshire. The term ' Grindslow Shales ' has been used recently by Mr. Jackson for the beds between the Kinderscout Grit and the Shale Grit,[2] and for this area affords a closer definition than the ' Sabden Shales ' used in Sheet 77.

[1] Holroyd, W. F., and J. Barnes, 'Rocks and Fossils of the Yoredale Series of the Marsden and Saddleworth Valleys,' *Trans. Manchester Geol. Soc.*, vol. xxiv, 1896, pp. 70-99.

[2] Jackson, J. W., 'Succession below the Kinder Scout in N. Derbyshire,' *Journ. Manchester Geol. Assoc.*, vol. i, 1927, pp. 15-32.

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The Kinderscout Series may attain a thickness of as much as 600 feet. It consists entirely of coarse pebbly grit with a number of shale partings; flaggy beds, however, occur locally. The lowest member is usually thick, sometimes up to 300 feet. In the uppermost shale parting Mr. Edwards finds a band of black shale with *Lingula* and lamellibranchs, the equivalent of the 'cf. *Allorisma* band' of Bisat[1]; this bed was found in many parts of the Huddersfield area by Dr. Wray and others, and is well developed in the Wessenden valley; but in the country immediately north of Crowden it appears to have died out.

Within a few feet of the top of the Kinderscout Grit is the marine band with *Reticuloceras reticulatum* mut. α, which is everywhere well developed and easily detected, as indeed are several of the succeeding bands; the cloughs which converge on Holme in the centre of the Sheet afforded Mr. Bisat his type sequence. Brachiopods and gastropods have been found in addition to the more abundant groups.

The succeeding measures up to the White Rock vary to some extent from those proved in the area to the north. A comparatively short distance above the mut. α bed is a sandstone followed immediately by a bed with mut. β; in Ramsden Clough the top surface of the sandstone is mammillated and the goniatites can be found in the shale occupying the hollows. This band appears to be the only one in this area containing mut. β and is presumably the same as the most persistent of those found in the Huddersfield district; the sandstone would then be a representative of the Readycon Dean Series or Scotland Flags. In the south-east the 'Rivelin Grit' of the original survey[2] appears to be partly on the same horizon.

For the next important rock the name 'Heyden Rock' is proposed; this is the 'main third Grit' of the district and has been called the Pule Hill Grit in the north-western part of the area. In the valley of the Heyden Brook, near the middle of the area, it is well exposed and has been largely worked, the 'old quarries' being marked on the one-inch map. Its exact position in the sequence of marine bands is here accurately defined, as there are good exposures of the mut. γ and mut. β bands above and below it respectively; the latter band contains a conspicuous layer of large limestone nodules containing uncrushed specimens of the zonal and other goniatites. The conditions of deposition of these nodules have been such as to allow of the formation of petroleum from the animals inhabiting the shells. Mr. Edwards has found a *Lingula* band in a shale parting in the Heyden Rock. The sequence of the overlying shales varies somewhat, but in many parts they contain a thin rib of sandstone, not exceeding 10 feet thick overlain immediately by a band with dwarf *Lingula*; some 20 feet higher is the mut. γ

[1] *Naturalist*, 1920, p. 350; 1921, pp. 9, 10.
[2] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 36.

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band which is often found to form the roof of a thin coal or smut. The succeeding shales are sandy and rapidly merge into the white Rock.

The White Rock is everywhere well developed and occupies large areas of moorland on either side of the Yorkshire and Cheshire boundary in the central area. The top is a ganister which is succeeded by the Upper Meltham Coal. The Lower Meltham Coal is not persistent; it occurs below the mut. γ band with a bed of ganister as its seat; both coal and ganister have been worked south of Meltham.

The normal sequence above the White Rock shows shales containing the Cancellatum and Cumbriense Bands followed by the pebbly Rough Rock. In last year's *Summary* it was pointed out (pp. 44, 45) that a sandstone occurs locally between the two marine bands on the high ground south of Meltham; this sandstone reappears in the country west of Langsett, but not elsewhere; it would seem that we are dealing with isolated sand banks formed at a time when mud was being deposited over the greater part of the area. An interesting point is the occurrence of *Carbonicola* bands in these shales. In recent borings in the Huddersfield area Dr. Wray has found one between the White Rock and the Cancellatum band; at Meanwood, near Leeds, Professor Gilligan has recorded the 'intercalation of a *Carbonicola* bed between two marine bands,' presumably those of Cancellatum and Cumbriense[1]; Mr. Edwards has now detected a third lying between the Cumbriense band and the Rough Rock in surface exposures near Langsett. These occurrences confirm the conclusion already drawn from the goniatites that the Lower Coal Measures should on palaeontological lines be extended downwards to the top of the White Rock instead of the top of the Rough Rock.

The remaining part of the sequence of strata exposed in the area of Sheet 86 (Glossop) calls for no special comment here. Mr. Bromehead and Dr. Wray have mapped beds up to the Parkgate Coal in the Denby Dale and Cawthorne area, where the *Carbonicola* band in the roof of the Wheatley Lime Coal forms a useful guide.

A large number of photographs has been taken by Mr. Rhodes in the area of Sheet 86; enlargements of a few of these, together with specimen maps, etc., were exhibited at the annual meeting of the Yorkshire Naturalists' Union held at York in December.

C. N. BROMEHEAD.

[1] *Trans. Leeds Geol. Assoc.*, pt. xviii, 1920, p. 16.

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4. LANCASHIRE DISTRICT

Headquarters : Manchester

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L. H. TONKS, M.Sc.
R. C. B. JONES, M.C., M.Sc. } Geologists.

In Lancashire Sheet 85 (Manchester), the standardization of the six-inch maps has been completed, and these maps are now being published, while the preparation of the one-inch map is well advanced. A descriptive memoir of this area is now being written.

Several underground tunnels in metals below and above the Roger Mine in the Oldham area have been examined and collections from the fossiliferous horizons have been made by Mr. Hester. Examination of the fossils from these beds has afforded an effective correlation throughout this particular district, which confirms approximately but not in all detail the interpretation given in the mining records. The band between the Roger and Furnace Mines is known to some of the collieries as an index horizon. It yields *Anthracomya pulchra* in abundance.

In Sheet 84 mapping has been carried on throughout the summer on the Coal Measures of Wigan and St. Helens. Exposures are few, the ground being for the most part thickly covered by drift, and, until the available mining information is sifted, few conclusions can be drawn as to correlation or structure. A great diversity of nomenclature, combined with the fact that the same name is not infrequently applied to different seams, makes comparison with known areas difficult in the early stages of the work. This difficulty has been experienced by Dr. Sherlock in the St. Helens area, where all the coals have local names, the easily identified Arley Mine being for instance known as the Little Delf. The King Mine of St. Helens is identical with the Rushy Park Mine and is much lower in the succession than the King Mine of Wigan. Some of the seams such as the Sir John Mine may be local and without equivalent beyond the district.

Coal mining has been carried on around St. Helens during a long period and there are many worked out mines. The active collieries are for the most part situated along the southern margin of the exposed coalfield or under the Trias beyond. The wedge of Trias faulted down between Thatto Heath and Prescot suggests possibilities of reserves which, so far, have not been fully prospected.

In the Upholland area, where Mr. Tonks has been working, the succession above the Lower Mountain Mine appears to be very much expanded in comparison with that of the Rossendale area. The Lower Mountain Mine is got for coking at a colliery near Upholland Station and crops in the railway cutting west of the Upholland

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Tunnel. In the cutting a hard siliceous sandstone, strongly reminiscent of the Ganister Rock of the Bacup area, lies below the Lower Mountain Mine, and is about 100 feet thick. The shales above the Lower Mountain contain *Carbonicola* and pass up into shaly sandstone; the Bullion Mine Rock, with the Upper Foot Mine and its marine band is visible at the end of the section.

The shales below the Orrell Five Foot Mine (Three Quarters or Smith Mine) are worked for brickmaking near Orrell Station, and the *Carbonicola* band which occurs about 60 feet below the Three Quarters Mine in the Atherton area has been found in a drain leading from the brickyard to a culvert under the railway.

Glacial striae have been observed on the surface of the massive fine grained sandstone, Old Lawrence Rock, which is extensively quarried at Appley Bridge. Several striated surfaces are visible south of the Appley Road quarry on the west side of Appley Lane, 350 yards north-west of Appley Bridge Station. The most numerous striations run E.12°S., but there are others which vary in direction between E.18°N. and E.20°S.

Mapping has been continued by Mr. Jones in Sheet 84 (Wigan), where the greater part of the area between Horwich, Wigan and Leigh is found to be drift covered. Boulder-clay predominates, particularly to the west and north-west of Leigh.

Exposures of the Coal Measures are confined to the valley of the River Douglas as far south as Wigan, and to the high ground about Haigh and to the south of Standish. The sections along the Douglas figured by Hull[1] are now almost completely obscured.

In a disused brick-pit beside the railway about 1 mile north-east of Red Rock Station a remarkable strike section is visible. Dark blue shale with thin ironstone bands is seen to cut across the underlying blue-grey mudstone and an 8 ft. bed of flaggy sandstone with an unconformable junction. The line of this junction is clean and sharp and forms an angle of about 5° with the strike of the beds below. No discordance in the amount of dip has been observed.

Considerable spreads of sand and gravel have been mapped to the west and south of Adlington and are well exposed in sand-pits about ½ mile west of the church. Here the sand is overlain by 3 ft. of stony red boulder-clay. Another large area of sand occurs to the north and east of Wigan and extends up to Standish, and on the east side of the river Douglas below Haigh Park. The relations to the boulder-clay are not so clear in this area. Sands north of Hindley, which extend to the east to beyond Daisy Hill, are seen to pass below boulder-clay to the south.

W. B. WRIGHT.

[1] 'The Geology of the Country around Wigan' (*Mem. Geol. Surv.*), 1862.

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5. CUMBRIAN DISTRICT

Headquarters: London

BERNARD SMITH, M.A., Sc.D., District Geologist.
E. E. L. DIXON, A.R.C.Sc., B.Sc. } Senior Geologists.
T. EASTWOOD, A.R.C.Sc. }
F. M. TROTTER, M.Sc. } Geologists.
S. E. HOLLINGWORTH, M.A., B.Sc. }

The re-survey of Sheets 22 (Maryport) and 18 (Brampton) being completed, work was commenced on the northern margin of the Lake District north and east of Cockermouth (Sheet 23) by Messrs. Eastwood, Trotter and Hollingworth during a short field-season in 1928. The first-named studied part of the coalfield near Aspatria and the Carboniferous Limestone in the neighbourhood of Wardhall and Bothel as well as Skiddaw Slates south-east of Bothel; whilst the two latter, working in the central and east-central parts of the district near Uldale and south of Caldbeck respectively, grappled with the Borrowdale-Skiddaw Slate-Carrock Fell sequence and part of the succeeding Carboniferous Limestone Series.

Useful information about the volcanic and intrusive rocks has been obtained from this preliminary study, but further results must await the microscopic examination of the large number of rock specimens collected and those which will be secured in future, and also the correlation of the incomplete sequences determined at different points along the outcrop.

Skiddaw Slates.—Mr. Eastwood reports that in the area south-east of Bothel the general strike of the upper part of the Skiddaw Slates—in spite of many variations—is about east-north-east to west-south-west and the dip northerly. Hard sandstones, referred to the Watch Hill Grits,[1] occur in Blumer Beck east of Sunderland. These are succeeded by alternations of pale and dark mudstones which pass up into striped grey sandy shales with nodules and thin bands of hard fine sandstone. Farther east, near Bridgfield, west of Overwater, Mr. Trotter finds that the Skiddaw Slates pass conformably upwards into the Borrowdale Volcanic Series.

In the Caldbeck Fells the lowest beds mapped by Mr. Hollingworth belong to the Skiddaw Slates. No fossils have been found in them as yet, but their lithology and position suggest that they represent the higher beds of the series, being similar in type to the Mosser Slates of West Cumberland.[2] They have been studied principally around Great Sca Fell, where they lie in closely packed isoclinal folds. Grits of Watch Hill type form the top of Great Sca Fell, Little Sca Fell and adjoining heights, and have been proved to extend considerably to the north of their previously known limits.

[1] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 71.
[2] *Ibid.*, p. 71.

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Their exact relationship to the contiguous ' slate ' has not yet been determined. To the north the Skiddaw Slates are succeeded by Borrowdale volcanics.

Borrowdale Volcanic Series.—In the greater part of the ground examined by Mr. Eastwood the Borrowdale volcanic rocks are absent by pre-Carboniferous denudation, but at Bothel Craggs, farther east, porphyritic lavas of ' Eycott type,' associated with fine grained lavas and coarse tuffs, make their appearance. Still farther east the Borrowdale rocks appear in strength and have been mapped by Mr. Trotter between Binsey and Longlands Fell. The rocks here are uncleaved, and reliable dips, invariably at a steep angle to the north, were obtained; so that a definite, although incomplete, sequence was recognised. It comprises a succession of andesites and tuffs which has proved to be identical to that recently made out independently by Mr. T. C. Nicholas.[1]

A lava approximately 15 feet in thickness, identical in hand specimens to the bytownite-bearing lavas of Eycott Hill, is the lowest horizon definitely occurring within the volcanic sequence; but a shale breccia, displaying sedimentary banding, which underlies the lava and is faulted against the normal Skiddaw Slates, may prove to be a tuff. A second ' Eycott-type ' lava is separated from that above mentioned by a normal andesite sandwiched between two bands of shale of Skiddaw Slate type (each tuffaceous near its base), and is overlain by two belts of tuff parted by a dark-blue flinty lava of variable thickness. The upper tuff is followed by a group of normal green andesites, with occasional phenocrysts of augite, which appears to lie below a group of ' Eycott-type ' lavas, succeeded in turn by normal andesites.

The lower beds of the series are well exposed in the reservoir section north-east of Overwater and in the neighbourhood of Scawthwaite. Higher beds appear in the stream sections on Binsey and Longlands Fell.

In the ground mapped by Mr. Hollingworth, farther east, the exact relationships of the Skiddaw Slates to the Volcanic Series are obscure, but in the latter there appears to be a general upward sequence northwards. The lowest beds apparent form a group of green tuffs, with scattered fragments of pinkish felsite, associated with porphyritic augite andesite lavas. In the Dale Beck region a great thickness of fine-grained massive bluish andesites forms the crags west of the old Roughton Gill Mine. Their relations to the tuffs are rather obscure. They are followed by vesicular and fine-grained greenish andesites, succeeded by a well marked group of lavas indistinguishable in the field from the coarsely porphyritic lavas of the Eycott Hill-Berrier region lying to the south-east. Associated with these are fine-grained andesitic types and pinkish

[1]Mr. Nicholas not only generously communicated some of the results of his unpublished work, but also spent several days in the field with Mr. Trotter or other members of the unit.

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rather acid looking rocks, the margins of which locally suggest intrusive relationship. Observable dips are scarce in these rocks, weathered outcrops, which might exhibit banding or bedding, being practically non-existent.

Dark-bluish compact and greenish vesicular andesites in some variety occupy a belt of country north of the 'Eycott' types. These in turn are succeeded by a group of tuffs, frequently quite coarse in texture. Acid fragments of a pale silver-grey colour are a characteristic feature of this group, which, when traced westward, is cut out by the overstep of the Basement Beds of the Carboniferous Limestone Series.

Intrusions.—Small areas of the western part of the Carrock Fell intrusive complex have been mapped by Mr. Hollingworth about the head of Roughton Gill. Part of this ground had been included previously in the Borrowdale Volcanic Series. A deposit of china-clay, which was once worked to a small extent north of Great Lingy Hill, lies on the northern margin of the intrusive complex and may be related to it. Kaolinization is widespread in the immediate neighbourhood.

A number of small dykes, frequently associated with basic material so as to form composite intrusions, pierce the lower part of the crags west of Roughton Gill Mine. They have an east and west trend and die out upwards. In hand specimens their appearance suggests an origin from the Carrock Fell complex—or, in view of their trend, a derivation from an underground extension of that magma.

Carboniferous Basement Beds.—The basement beds, of supposedly Carboniferous age, which underlie the Cockermouth Lavas in the western part of the district,[1] are represented also in the areas mapped by Messrs. Trotter and Hollingworth, but the overlying lavas appear to be wanting. Exposures in stream and ditch sections examined by Mr. Trotter prove that a large drift-covered area south of Uldale, previously considered to be underlain by volcanic rocks, is really occupied by red and green marls (or shales) with conglomerates.[2] Mr. Hollingworth finds the same state of affairs farther to the east.

Carboniferous Limestone Series.—From Sunderland westward to Wardhall Common the ground is occupied by part of the Carboniferous Limestone Series, largely masked by Glacial drift. The West Cumberland sequence from the 7th to the 1st Limestone has been recognised by Mr. Eastwood, but much further work remains to be done here owing to numerous faults. Quarries and trial holes around Wardhall, exposing limestones from the 1st to

[1] Eastwood, T., 'The Cockermouth Lavas, Cumberland,' 'Summary of Progress' for 1927 (*Mem. Geol. Surv.*), Pt. II, 1928, p. 16.

[2] Recognised by Mr. K. W. Earle, 'The Lower Carboniferous Rocks of Cumberland,' *Geol. Mag.*, 1922, p. 525.

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below the Girvanella Band[1] (base of D_2) near the bottom of the 4th Limestone, show that the limestones are here more widely separated than in West Cumberland. The Orebank Sandstone Series, which is considerably thicker, consists largely of shale, while a fairly thick belt of sandstone intervenes between the 3rd Limestone and the Junceum Beds and may be responsible for the absence of the 'Chert Beds' usually found at the top of the 4th Limestone. The latter, again, is more definitely split up by belts of shale and sandstone. It is noteworthy that a double coal, with a parting containing large Productids, which occurs at the base of the Junceum Beds at Broughton Craggs near Cockermouth, is present in the same position at Wardhall.

Near Udale a small area of the Limestone Series has been mapped by Mr. Trotter, who recognises both the Upper and Lower Dibunophyllum Zones; whilst the upper part of the Upper Seminula Zone (S_2) is probably present immediately above the Basement Beds. Here also the sequence is considerably thicker than in West Cumberland owing to the incoming of several beds of sandstone.

Limestones of D_1 age were examined by Mr. Hollingworth in a number of small quarries east of Nether Row. Lithologically they are strikingly similar to beds of that age both in the Pennines and in the ground studied by Mr. Eastwood.

Coal Measures.—The Coal Measures studied by Mr. Eastwood present no novel features beyond the fact that the deterioration of the Main Band, which sets in about Bulgill, is further accentuated in the Aspatria area, with the result that the Cannel and Metal Bands (parts of the split Main Band) are worthless. Many of the other seams also deteriorate in this direction; the Yard Band, on the other hand, improves and becomes an excellent seam.

Glacial.—The composition of the boulder clay and outwash moraines in the Ellen Valley and the trend of the drumlins indicate that a glacier from the northern slopes of Skiddaw filled this depression. Deltas and overflow channels noted by Mr. Trotter indicate that a glacier lake at 500 ft. O.D. occupied the Ellen Valley near Ireby during the recession of the ice after the Ellen glacier had split off from the main ice sheet to the north.

BERNARD SMITH.

[1] The position of this band was pointed out to us by Mr. C. Edmonds, of Moor Row.

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6. NORTHUMBERLAND AND DURHAM DISTRICT

Headquarters : Newcastle-on-Tyne.

R. G. CARRUTHERS, District Geologist.
G. A. BURNETT, B.Sc.
A. FOWLER, M.A., B.Sc.
W. ANDERSON, M.Sc.
} Geologists.

During the past year most of the Newcastle staff were engaged on office work, Mr. Anderson being the only one stationed in the field. He revised the north-eastern part of Sheet 8 (Elsdon), round Harbottle, Holystone, and Hepple. Much interest attaches to the development of the Scremerston Coal Group hereabouts; marine limestones begin to appear in fair number, as opposed to their rarity in more northern areas; the whole assemblage takes on an increasingly marine facies, in conformity with the change known to set in towards the Pennines.

Several bores and sinkings were examined during the year, notes on the more important being appended.

Tuedian.—The Cementstone Group along the Coquet valley shows one or two abnormally thick limestones, in continuation with those already noted towards Rothbury; the old quarries at Hetchester were in a bed quite 15 feet thick. In the burn below Whitefield House, south of the great Swindon Fault, the second limestone below the Fell Sandstone has a well-marked band of *Ortonella* concretions; this seems to be a widespread horizon in the north-west of Northumberland, and may be the equivalent of that noted by Professor Garwood as marking the base of the *Seminula gregaria* sub-zone in Ravenstonedale.[1]

The Fell Sandstone is responsible for much high, craggy ground south and west of Harbottle. There is lenticular bedding on a large scale amongst the coarse grits of this series, along with much repetition by east-north-east step-faults.

Scremerston Coals.—This series is prominent on either side of the Grasslees Burn, north of the Swindon Fault. Two coals have been wrought there, each reported to be 3 feet thick: the lower one (possibly equivalent to the Plashetts Coal) can be followed for many miles to the north-west, being repeated by step-faulting at Headshope and Wilkwood East. Below these coals, and only about 100 feet above the top of the Fell Sandstone, fossiliferous shales have been noted in the stream south of Swindon. A layer rich in crinoid debris and small ribbed shells, along with bryozoa, is found there. Over this some dark shales have yielded *Sphenopteris filiformis* Kidst., *Diplotmema patentissimum* (Ettingshausen) and other genera,

[1] Garwood, Prof. E. J., *Proc. Geol. Assoc.*, vol. xxvii, part i, 1916, pp. 1-10 and p ate 18.

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identified by Mr. Burnett. This discovery is of value, owing to the extreme rarity of identifiable plant-remains among Scremerston strata in general. Furthermore the crinoid bed shows that marine intercalations are present in this area at a very low level in the series: above the two coals they appear in stronger force, eight or nine limestones being found, from the Redesdale Limestone upwards; one of them (the Fourlaws Limestone) has a well-known workable coal above it. None of these limestones can be correlated with the Dun, which elsewhere marks the upper limit of the Group. Perhaps all of them may eventually be included within the Scremerston measures, but until more work is done this point must remain unsettled.

Glacial.—The later movement of the ice-sheet over the Harbottle area was east-north-east, and there are striae in this direction on Harbottle Hill. On its retreat this 'western ice' seems to have initiated, as a lateral feature, the gorge of the Coquet at Barrow Scars. Originally the river took a winding course round the foot of Calf Lee and Barrow Hill, now occupied by relatively unimportant streams. There was another diversion, of much smaller size, from the south to the north side of Harbottle village.

In addition to his field work, Mr. Anderson examined two deep borings put down by Synthetic Ammonia and Nitrates, Ltd., about one mile east of Billingham. Under nearly 100 ft. of drift, red Triassic sandstones predominated down to 400 ft., followed by 240 feet of red marl with occasional bands of sandstone and gypsum. Beneath came massive anhydrite, with subordinate beds of red marl and gypsum, the whole resting conformably on Magnesian Limestone. The junction of the Limestone (a buff-coloured, compact dolomite) with the anhydrite was examined both in the bores and in the two shafts completed in 1927: in all cases the passage downwards was gradual, the anhydrite being increasingly interleaved with bands of fibrous gypsum and well-bedded dolomite until the latter alone was present. In this dolomite are innumerable tubes of *Filograna* (?) *permiana* King, and occasional examples of *Mytilus squamosus* J. de C. Sowerby, *M. septifer* King, and *Schizodus schlotheimi* (Geinitz).

In the Coal Measures, Mr. Fowler has reported on a shaft recently completed at Lynemouth, near Ashington. The drift cover (65 feet) is heavy and rests on a 10-fathom bed of sandstone, much quarried round Woodhorn. At 80 fathoms the High Main Coal was reached and 7 fathoms above this was a band of estuarine lamellibranchs, well known elsewhere in the Ashington field.

Mr. Burnett dealt with the important sinking at Seaham Harbour, Co. Durham, which was completed early in the year. The two shafts passed through 420 feet of Magnesian Limestone, with 51 feet of yellow sands beneath: freezing was necessary here. The underlying Coal Measures had at least eight workable coals, ranging down

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to the Hutton seam. Plants, all of Yorkian facies, were got at many levels. The Low Main roof was rich in *Calamites*, but though fern-like plants were noticed at intervals, no band seemed to be of diagnostic value. There were several 'black bat' horizons, rich in *Carbonicola*: it is possible that some may be of value when our knowledge of the district is more complete.

A pipe-line recently cut down Benwell Bank, Newcastle, showed indurated and strongly reddened sandstones, broken and freely jointed, with partings of red shale, the whole resting directly on a 4-ft. coal, bituminous and unburnt. The alteration of the roof strata evidently dated from the great fire in the High Main Coal, known to have occurred hereabouts over two hundred years ago. A mile to the north there is a complete section of the High Main, 8 feet thick, in a clay-pit. The upper 4 feet is of distinctly better quality than that below, and it would seem that this upper part alone was wrought on Benwell Bank, the burnt-out galleries eventually collapsing on to the 'pavement coal,' kept cool by air passing inwards.

R. G. CARRUTHERS.

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(B)—SCOTLAND

1. AYRSHIRE

E. B. Bailey, M.C., B.A., District Geologist.
V. A. Eyles, B.Sc.
J. B. Simpson, B.Sc.
W. Q. Kennedy, B.Sc.
} Geologists.

Owing to pressure of indoor work only a small area near New Cumnock, in one-inch Sheet 15, was revised. Attention was limited to Carboniferous rocks and neighbouring outcrops of Upper Old Red Sandstone. Mr. Simpson worked in two areas, one south of the Nith at New Cumnock and the other near Dalblair on the Glenmore Water. Mr. Eyles mapped in the intervening district north of New Cumnock. Mr. Kennedy was only available for a very short time.

Calciferous Sandstone Series.—On Sheet 15 (Sanquhar) an elongated strip of 'intrusive doleritic rock,' ¾ mile long, is shown outcropping about 3 miles north-north-east of New Cumnock. Only two exposures occur, one in a stream running north to join the Glenmore Water a little west of Dalblair, the other one-third of a mile to the east-south-east, in a small disused quarry. At the former locality olivine-basalt of Dalmeny type is exposed along the stream bed for some 200 yards, and the outcrop appears to include at least two lava flows. The top of the lower of these is vesicular, with sediment bedded into cracks and cavities, leaving no room for doubt that it is in fact a lava flow and not an intrusion. The basalt in the quarry is of similar type to that of the stream. None of the known intrusive rocks of the district is of this type, and there seems no doubt that the quarry exposure is a continuation of the lava horizon. No other exposures of Calciferous Sandstone lava have yet been met with in this district, and it is uncertain whether this volcanic horizon is continuous with that which occurs farther north near Airds Moss.

Lower Limestone Group.—Two miles south-south-west of New Cumnock, in the Connel Burn, a limestone is exposed, which has been hitherto placed at the top of the Carboniferous Limestone Series. The presence in it, however, of *Productus giganteus* (Mart.) points to its being a member of the Lower Limestone Group, or of the top part of the Calciferous Sandstone Series. Coal Measures come on a short distance to the north, and it is clear that they must be separated from this limestone by a powerful fault cutting out most of the Limestone Coal Group, the Upper Limestone Group, the Millstone Grit, and a part of the Coal Measures. The direction of this fault is north-east, but it is nowhere exposed at the surface in the area surveyed.

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Upper Limestone Group.—The Index Limestone, characterised by the presence of abundant *Productus latissimus* J. Sow., has been recognised in two localities in the New Cumnock district. The first of these lies south of the River Nith, in Redree Burn, about 300 yards south of the farm of High Polquhirter. North of the river Nith the same limestone may be seen in the stream bank immediately to the east of Mansfield House.

Coal Measures.—Exposures of this group are scanty, but we are indebted to the New Cumnock Colliery Company for kindly supplying us with many valuable mining and boring records. A study of these has revealed the fact that the Productive Coal Measures of this area have a thickness of about 215 fathoms.

E. B. BAILEY.

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2. LANARKSHIRE AND PEEBLESSHIRE

J. E. Richey, M.C., B.A., District Geologist.
H. H. Read, D.Sc., A.R.C.Sc. } Senior Geologists.
J. Phemister, M.A., D.Sc. }
G. Ross, B.Sc. } Geologists.
W. Q. Kennedy, B.Sc. }

In southern Lanarkshire (Sheet 15), the mapping of the Douglas Coalfield has been completed by Mr. Ross, and the memoir is in preparation.

In Peeblesshire (Sheet 24), the revision of the pre-Carboniferous Limestone rocks has been nearly completed by Drs. Read and Phemister and Mr. Kennedy. Some re-mapping of the Carboniferous Limestone strata that extend southwards into Sheet 24 from the Midlothian Basin (Sheet 32) was carried out by Mr. Richey, who also visited various Midlothian sections in connexion with the preparation of a new colour-printed edition of Sheet 32.

Dr. Read and Mr. Kennedy supply the following account of their work in the West Linton district of Peeblesshire.

Old Red Sandstone.—The north-easterly thinning of the Lower Old Red Sandstone lavas of the Biggar Centre, noted around Dolphinton,[1] continues into the West Linton district. Here, the great flow of acid lava that forms Black Mount, Dolphinton, is represented by a thinner development making up the ridge that ends in Mendick Hill. Farther north-east, the acid flow occurs as a narrow belt in the West Water at North Slipperfield. In the same burn, due north of South Slipperfield, a thin flow of amygdaloidal andesite is found. This and the North Slipperfield rock are alone left to represent the great lava-pile of the Biggar district. In the Lyne Water, between the Pentland Fault and West Linton, there are conglomerates, grits and sandstones, together with an extensive development of yellow-weathering 'claystones' that appear to be brecciated rhyolitic flows.

North-west of the Pentland Fault, in the upper valleys of the Lyne and West Waters, the southern part of the Lower Old Red Sandstone of the Pentland Hills is represented by sediments with quite subordinate lavas. These rocks are covered unconformably by friable, bright red sandstones belonging to the Upper Old Red Sandstone, of which the ridges of Catstone Hill, Fadden Hill and Craigengar, and the north part of Byrehope Mount, are composed. Like the volcanic rocks of the Biggar Centre, the lavas of the upper parts of the Lyne and West Waters decrease in importance towards the north-east. Thus, in the West Water there are possibly a dozen fairly thick flows, whilst to the north-east, in the Lyne Water, lavas

[1] Read, H. H., in 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, p. 107.

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are limited to a narrow zone next the Pentland Fault. Among the sedimentary rocks, a characteristic type is a coarse purple sandstone with very large plates of white mica. Conglomerates and greenish pebbly sandstone occur throughout.

In the Lower Old Red Sandstone of this part of the Pentland Hills thin sills of microdiorite are frequent, and are usually intrusive into conglomerate. A good example of a tapering sill is seen in the Lyne Water just below Cairnmuir (Baddinsgill).

Pleistocene.—In a sand-pit immediately north of Baddinsgill laminated clays rest on false-bedded sand and are overlain by sands and gravels. Traces of the same group of clays have been noted lower down the Lyne Water nearly to Wakefield, where they rest on boulder-clay. These clays, and the associated sands and gravels, are connected with the retreat-stage of the local glaciers.

J. E. RICHEY.

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3. FIFE AND KINROSS

J. E. RICHEY, M.C., B.A., District Geologist.
D. HALDANE, B.Sc.
J. K. ALLAN, M.A., B.Sc. } Geologists.
J. KNOX, B.Sc.

During the past year, Messrs. Haldane and Allan have been almost entirely engaged in office work in connexion with the Fife Coalfield. Mr. Knox, on returning from Orkney, continued his survey of the Dysart area northwards to beyond Leslie and Cadham, and supplies the report given below. The geological structure is much obscured by extensive spreads of sand and gravel and boulder-clay, often of considerable thickness. Rock-exposures are infrequent, and usually consist of dolerite sills intruded into sediments of Lower Limestone and Limestone Coal Group age. In this difficult area boring information has proved of value.

Lower Limestone Group.—In a quarry near the farm of Stenton, 2 miles south-east of Leslie, a hard, dark limestone, containing productids, crinoid stems, and corals, is seen dipping steeply to the west and north-west. The total thickness of limestone exposed is about 12 feet. In the Geological Survey Memoir on Central and Western Fife,[1] it is referred to as the Levenseat Limestone, and appears as such on the published map[2] of the district. Recent boring information has, however, thrown considerable doubt upon this correlation, and a consideration of the probable structure strongly suggests a horizon in the Lower Limestone Group rather than the Upper. Fossil evidence, though scanty, supports this view. One specimen of a coral collected from this limestone has been determined by Mr. Pringle as *Aulophyllum sp.*, a genus which is recorded in the memoir above referred to as having been obtained from only four Fifeshire localities, from strata of Lower Limestone Group age, three being from the Charlestown Main Limestone.[3] The available information, therefore, is considered sufficient to correlate the seam at Stenton with the Charlestown Main Limestone.

The above correlation necessitates the introduction of a powerful east-west fault passing immediately south of the quarry at Stenton, in order to bring in the Upper Limestone Group to the south. The existence of this fault is also indicated by bores, and it appears probable that to the east of Stenton the fault assumes a north-easterly direction, passing beneath the south end of Markinch to become continuous with the large east-west dislocation which has long been known to separate the Coal Measures of the Balgonie Basin to the south from the Carboniferous Limestone Series beneath Markinch and Star to the north.

[1] Geikie, Sir A., 'The Geology of Central and Western Fife and Kinross' (*Mem. Geol. Surv.*), 1900, p. 135.
[2] Geological One-inch Map of Scotland, Sheet 40, 1898.
[3] *Op. cit.*, p. 221.

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Limestone outcrops at Balgeddie and Pitkevy have also been investigated. At the disused Rothes Lime Works, 150 yards south-west of Balgeddie farm, and about half a mile north of Leslie, the following section is exposed in the eastern bank of the Lothrie Burn.

	Ft.	In.
Fakes and faky blaes		
Sandstone, brown, faky	2	0
Blaes, dark blue, mostly barren, lowest 3 in. abundantly fossiliferous (crinoid stems, brachiopods, lamellibranchs, trilobites, etc.)	24	0
Limestone, hard, dark, upper half almost barren, lower half full of crinoid stems	1	2
Limestone, hard, bluish-grey, upper 9 in. crinoidal and with a few shell fragments, lowest 6 in. darker, impure, with a few crinoid stems ...	2	0
Limestone, brown, sandy (base not seen)	1	6

At the top of the river bank and lying some 20 feet above the brown faky sandstone, the base of a dolerite sill is seen.

At Pitkevy, about three-quarters of a mile north-west of the above exposure, there is an old limestone quarry, now completely overgrown, but a south-easterly dip of the strata in this vicinity is indicated by an exposure less than 100 yards south-east of the quarry, in the east bank of a small ravine. There, sandy shales, slightly baked, are seen dipping below fine-grained dolerite. In the memoir already cited,[1] the limestones occurring at Balgeddie and Pitkevy, and a third outcrop farther north at Easter Glasslie, are described as detached outliers of the Hurlet Limestone isolated from one another by the injection of the great dolerite sheets of the Lomonds. Absence of intermediate exposures precludes the possibility of asserting whether this is the case or not, but the available evidence does not suggest transgression of the intrusive sheets. The limestone at these three localities (Balgeddie, Pitkevy and Easter Glasslie), previously regarded as the Hurlet seam of the west of Scotland which marks the base of the Lower Limestone Group, is probably the Charlestown Main Limestone which, in the Leslie area, lies some 30-40 fathoms above the base of that group as now defined.[2] No outcrop of any other of the limestones of this group is known in the district so far surveyed around Leslie and Cadham, but their occurrence is proved in a number of bores south of Cadham. The presence of extensive east-west faulting is also disclosed by these bores.

J. E. RICHEY.

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[1] *Op. cit.*, p. 92.

[2] Dinham, C. H., in 'Summary of Progress' for 1923 (*Mem. Geol. Surv.*), 1924, pp. 117-120.

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4. ORKNEY ISLANDS

G. V. Wilson, B.Sc., District Geologist.
J. Knox, B.Sc.
J. V. Stephens, B.Sc., B.Eng. } Geologists.

The survey of Orkney was continued during the past summer by the above named members of the Geological Survey Staff.

Work was restricted to the Mainland and a few adjacent small islands. Mr. Wilson and Mr. Stephens completed the mapping of the West Mainland, except for a small area near Finstown which was done by Mr. Knox, who also finished the survey of the East Mainland.

Middle Old Red Sandstone.—In the West Mainland the mapping of Messrs. Wilson and Stephens has tended to show that the numerous localities in the Stromness Beds from which well preserved fish remains have been obtained lie on the same geological horizon. It has also been noted that the various outcrops are separated by a series of faults with a general northerly trend, and down-throw in most cases to the east. It has not been possible to arrive at any definite conclusions as to the thickness of the Stromness Beds that lie below the fish-bed, but at least 2,000 feet of strata that are thought to be in this position can be seen in an unbroken sequence along the coast of Birsay to the west side of the Broch of Birsay. A tentative base for the Rousay Beds has been taken below a band of grey flags, rich in fragmentary fish and plant remains, which lies about 50 feet below the lowest bed in which *Estheria membranacea* has been found. In the district from Evie to near the Chair of Lyde the position has been fixed fairly accurately, but southwards to Finstown, and eastwards along the southern slopes of Keelylang and Wideford Hills towards Kirkwall the ground is obscure and the line taken is only an approximate one.

Mr. Wilson noted the occurrence of a bed with good fish remains in a quarry at Gallowhall, near Evie. From this locality Mr. Strachan has obtained a number of fairly well preserved fish including *Coccosteus minor*. The bed is sufficiently calcareous to be burnt for lime, and lies about 100 feet above the base of the Rousay Beds. It is probable that this bed occurs at about the same horizon as that in East Hill Quarries, near Kirkwall, from which Hugh Miller[1] obtained numerous specimens of *Coccosteus minor*. If this supposition is correct it implies that a small patch of Stromness Beds lies to the south of Kirkwall. The bed exposed in Pickaquoy quarry to the west of Kirkwall is considered to be the basal *Estheria membranacea* band of the Rousay Beds. It is separated from the

[1] Miller, Hugh, 'Cruise of the Betsy,' 1858, p. 358, and Flett, Sir J. S., 'The Old Red Sandstone of the Orkneys,' *Trans. Roy. Soc. Edin.*, vol. xxxix, pt. ii, 1898, p. 388.

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eastern patch of Stromness Beds by a northerly prolongation of the fault which bounds the eastern coast line of Scapa Flow.

In the West Mainland an occurrence of *Estheria membranacea* has been noted by Mr. Stephens about a mile south of the Stenness Hotel. There is every reason to suppose that a small area of Rousay Beds forms the high ground of Ward Hill. In the Gorseness district of Rendall three beds containing *Estheria* have been noted in about 400 feet of strata. The lowest one is exposed along the coast and is supposed to be that which occurs just above the base of the Rousay Beds.

Owing to the faulted nature of the ground it is difficult to estimate the thickness of the strata that lie between the Stromness Fish Bed and the base of the Rousay Beds. It cannot, however, be much more than 1,000 feet.

Mr. Knox's mapping of the East Mainland shows that the structure of the ground between Deer Sound and Holm Sound is that of a broad anticline trending E.N.E. Rousay Beds occupy most of the ground, but the overlying Eday Sandstone and associated flags occur as a belt on the northern side and extend from Scapa Bay to Yinstay Head. On the south-east the Eday Sandstone is exposed from Dingyshowe to Notster. The structure of the southern part of Deerness is that of a syncline whose axis trends a little west of north. Beds of Rousay age are exposed on both sides and the fish-bed, which is characterised by the presence of *Dipterus valencienisii*, is well seen near Horraquoy on the east coast. A development of contemporaneous volcanic rocks occurs in the group of flags that are characterised by *Tristichopterus alatus*. Except at the Point of Ayre the exposures are poor. The rocks are highly decomposed, and it is very difficult to see what their field relations are. The red marly beds which overlie the *Tristichopterus* flags are seen in the centre of the syncline at Newark Bay.

Igneous Rocks.—Mr. Knox records the occurrence of a small volcanic vent on the shore of the parish of Holm, and about 230 yards south-east of the Tower of Clett. The exposure is only a few yards in extent and occurs in the face of a low cliff. The material of the vent consists of highly decomposed vesicular rock containing numerous rounded and subangular fragments of flagstone, up to 10 inches in diameter. The junction between the igneous material and the flagstones is seen on the north-west side. It is about vertical, and the surrounding sediments dip steeply towards the vent.

The best exposures of the previously mentioned contemporaneous volcanic rocks occur at the Point of Ayre, and probably also in the Black Holm of Copinsay. At the first mentioned locality the material consists of a highly decomposed vesicular basaltic rock. Its relations to the flagstones are rather obscure, but the presence, at the top, of large pipe amygdales, up to a foot in length, an inch in

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diameter and filled in with sandy material tends to prove that the rock is a lava flow. The rock which forms practically the whole of the Black Holm of Copinsay is similar in hand specimen to that of the Point of Ayre. It has a very irregular top and the hollows on its surface are filled in with unaltered shaly and sandy sediments. The exposure is separated by a fault from the Rousay Beds of the Corn Holm and the Ward Holm, but there is no reason to suppose that the rock is of different age to that at the Point of Ayre.

G. V. WILSON.

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III. SECTIONAL REPORTS

I.—PALAEONTOLOGICAL DEPARTMENT

In London

F. L. KITCHIN, SC.D., PH.D., F.R.S., Palaeontologist (District Geologist).

J. PRINGLE, Assistant-Palaeontologist } (Senior
C. P. CHATWIN, M.SC., Assistant-Palaeontologist } Geologists).

In Edinburgh

G. W. LEE, D.SC., Senior Geologist.

A. ENGLAND AND WALES

Two important additions to the series of Palaeontological Memoirs were made by the publication of Professor O. T. Jones's work entitled 'Plectambonites and Some Allied Genera' (vol. i, part 5 of the series), and Miss H. M. Muir-Wood's memoir 'The British Carboniferous Producti. II—*Productus* (*sensu stricto*); *Semireticulatus* and *Longispinus* Groups' (vol. iii, part 1). Professor Jones's monograph treats of certain British brachiopods of late Ordovician and Silurian age, many of which have previously been identified generically with *Plectambonites*, a distinct, early Ordovician generic group. In this work the later forms are fully described and are separated under new generic names. An important feature of the memoir is a comparative table of the British strata from the Llandeilo up to the Ludlow series. Miss Muir-Wood's memoir is a continuation of the work begun by the late Dr. Ivor Thomas on the Carboniferous Productids of this country, the first instalment of which was published in the same series in 1914. The fossils described in both these new memoirs are important in their stratigraphical applications.

During the year an enquiry concerning the occurrence of *Olenellus* in the Lower Cambrian rocks of South Wales again drew attention to a specimen collected by Mr. Pringle in the year 1908 from the red shales at Cwm-bach, near Pen-y-Cwm, Newgale. At the time of collecting the fossil was thought to represent the hypostome of an Olenellid trilobite, but as the locality is situated outside the area comprised in Sheet 227 no mention was made of the specimen in the memoir on that sheet. In view of the interest of the fragment, it has been submitted to Mr. E. S. Cobbold and Dr. F. Raw for a confirming opinion, and both agree that it is undoubtedly the hypostome of *Olenellus* or a closely allied genus. Since this probably constitutes the first known occurrence of an Olenellid in South Wales it seems worthy to be placed on record.

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The results obtained from the examination of a series of specimens stated, in a former publication, to come from the base of the Coal Measures exposed at Oldfields Limeworks, near the Wrekin, were regarded by Mr. Pringle as indicative of a Lower Carboniferous age. A visit to the locality was accordingly arranged, and the additional evidence collected by him and by Mr. S. W. Hester placed beyond question the assignment of these rocks to the Lower Carboniferous.

Amongst the fossils collected by Mr. W. Dewar from the Tarannon Shales of Hughley Brook and other localities in the Shrewsbury district, Mr. Pringle recognized several new species of corals. These are now in the hands of Dr. Stanley Smith for detailed study and description.

Several visits were made to the shaft-sinkings at Cefn-coed, near Neath, and in company with Mr. W. D. Ware, of Ystradgynlais, Mr. Pringle collected a representative suite of fossils from a marine band in the Coal Measures passed through in No. 2 Shaft. This marine bed is the highest of several similar beds lying between the Lower Pinchin and Red Vein coals, and collectively described[1] as the Cwmgorse Marine Beds. The shales have yielded a number of goniatites, several of which Mr. Pringle had previously shown to be identical with forms characteristic of the well-known Mansfield Marine Band.[2]

Certain specimens of *Nautilus nodiferus* Armstrong preserved in the Museum of Practical Geology have been studied by Mr. Pringle and Mr. J. W. Jackson in connexion with their paper showing the value of this shell as a guide-fossil. These authors have established a new genus for this interesting nautiloid, and have figured as *Tylonautilus nodiferus* a specimen from Claughton Brickworks, near Lancaster, exhibited in the Museum.[3] In Scotland *T. nodiferus* characterizes the Arden and Castlecary Limestones, and in the North of England, as far south as Derbyshire, the shell has been found in shales or in limestones referred in some districts to the Yoredale Series and in others to the Millstone Grit. As a result of their researches the authors have shown that this species, when accompanied by goniatites, is proved to be confined to beds just below the Bisulcatum Bed of Zone E of Mr. Bisat's zonal scheme of classification, and is associated with Lower Carboniferous plants. In fact the evidence brought forward in this paper shows that the dividing line between the Lower and Upper Carboniferous, based on

[1] Dix, Miss E., and A. E. Trueman, 'Boreholes in Cwmgorse Valley,' *Proc. South Wales Inst. Engineers*, vol. for 1928, pt. ii, pp. 63-130.

[2] Davies, J. H., and A. E. Trueman, 'A Revision of the Non-Marine Lamellibranchs of the Coal Measures, and a Discussion of their Zonal Sequence,' *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927 (in Discussion), p. 259.

[3] Pringle, J., and J. W. Jackson, '*Tylonautilus nodiferus* gen. nov.=*Nautilus* (*Discites*) *nodiferus* Armstrong: a Carboniferous Guide Fossil,' *The Naturalist*, 1928, pp. 373-378.

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the flora, agrees with the occurrence of many characteristic Avonian fossils in the uppermost part of the Carboniferous Limestone Series in the North of England and in Scotland, up to the level adopted for the junction between the Lower and Upper Divisions by the late Dr. R. Kidston. *Tylonautilus nodiferus* can be readily recognized, even when fragmentary, by its well-marked sculpture, and by reason of this fact and its narrow vertical range it has proved to be a valuable zonal fossil.

The collections of Cretaceous fossils have recently been enriched by some important additions of well collected material, including many choice specimens. The necessary work of naming, registering, and arranging these sets has been undertaken by Mr. Chatwin. The large series bequeathed by the late Dr. Benjamin Pope Bartlett, the result of more than twenty years of intensive collecting in the neighbourhood of Mere and Maiden Bradley, Wiltshire, gives a very full representation of the fauna of the Cenomanian and Albian beds in that area, and is illustrative of the paper by Dr. Bartlett and Mr. J. Scanes (*Proc. Geol. Assoc.*, vol. xxvii, 1916, pp. 117-134).

The late Gerard Weedon Butler also spent many years collecting, chiefly in the neighbourhood of Reigate, Surrey. His collection, comprising a large series of fossils from the Lower Chalk and also from the Lower Greensand, includes specimens illustrative of his papers ' On a Rich Fauna in the *varians* Zone of the Lower Chalk near Reigate ' (*Geol. Mag.*, 1920, pp. 269-271) and ' On the Perna Bed and the Weald Clay at Reigate ' (*Proc. Geol. Assoc.*, vol. xxxiii, 1922, pp. 313-318). A large proportion of this collection came from the area of Sheet 286, and will therefore form a valuable addition to Survey specimens obtained in that district. Similarly, the Chalk fossils from Western Surrey which formed the basis of Mr. G. W. Young's paper ' On the Chalk Area of Western Surrey ' (*Proc. Geol. Assoc.*, vol. xx, 1908, pp. 422-455) and were presented by him during the year, will serve as a useful supplement to the specimens collected officially from the area of the Aldershot and Guildford Sheet (285).

An extensive set of Cretaceous specimens from the collection made by the late G. W. Lamplugh, also recently dealt with by Mr. Chatwin, includes a fine series of the Lithistid sponges that characterize the Quadratus Zone of the Chalk in Yorkshire. A selected series of specimens from the Upper Chalk of Sussex, presented by Mr. C. T. A. Gaster, is illustrative of his recent work on the subdivisions of the Quadratus Zone on the south coast. Mr. Chatwin has incorporated the more important forms in the exhibited zonal series in the Museum.

The following specimens in the Museum have been figured, described or mentioned in publications :—

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IN THE PALAEONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1926
(Published 1928)

A Monograph of the Ammonoidea of the Gault. (Part vi)
By DR. L. F. SPATH, F.G.S.

Callihoplites patella *Spath*, pl. xxi, fig. 4, p. 192.
,, tetragonoides *Spath*, pl. xxi, fig. 3, p. 204.
,, vraconensis (*Pictet and Campiche*), p. 210.
Lepthoplites falcoides *Spath*, text-fig. 75c, p. 235.
,, ornatus *Spath*, text-figs. 78a, b, p. 239.
Schloenbachia subplana (*Mantell*), p. 239.
Pleurohoplites *cf.* renauxianus (*d'Orbigny*), pl. xxiv, fig. 9, p. 243 (3 specimens).
Arrhaphoceras studeri (*Pictet and Campiche*), p. 252.
,, precoupei *Spath*, pl. xxi, figs. 1a, b, pl. xxii, figs. 6a, b, p. 252.
Euhoplites lautus (*J. Sowerby*), *var.* biloba *Spath*, p. 263.

A Monograph of the Fossil Macrurous Crustacea of England. (Part v)
By MR. H. WOODS, M.A., F.R.S., F.G.S.

Mecochirus socialis (*Meyer*), p. 67.

A Monograph of British Dendroid Graptolites. (Part ii)
By DR. O. M. B. BULMAN, D.I.C., A.R.C.S., F.G.S.

Dictyonema irregulare *Hall*, pl. iii, fig. 4, p. 38.
,, sp. *d* ?, text-fig. 35, p. 64.

IN THE PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY OF LONDON, SERIES B, VOLUME CCXIV

VI.—*Croonian Lecture.—The Evolution and Origin of the Amphibia*
By PROF. D. M. S. WATSON, F.R.S.

Megalichthys sp., text-fig. 36, p. 250.

IN THE QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY, VOLUME LXXXIV

The Lower Carboniferous Rocks of the Menaian Region of Carnarvonshire: their Petrology, Succession and Physiography
By Dr. E. GREENLY, V.P.G.S.

V.—PALAEONTOLOGY

Corals

By DR. STANLEY SMITH, F.G.S.

Dibunophyllum turbinatum (*M'Coy*), p. 404 (9 specimens).
,, sp., p. 404 (4 specimens).
Clisiophyllum sp., p. 404 (2 specimens).

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Koninckophyllum magnificum *Thomson & Nicholson*, p. 404 (2 specimens).
,, sp., p. 404.
Caninia juddi (*Thomson*), p. 405.
,, sp. nov. i, p. 405 (2 specimens).
,, sp. nov. ii, p. 405 (3 specimens).
Lonsdaleia duplicata (*Martin*), p. 405 (12 specimens).
,, floriformis (*Martin*), p. 405 (12 specimens).
Corwenia rugosa (*M'Coy*), p. 406 (8 specimens).
Lithostrotion irregulare (*Phillips*), p. 406 (25 specimens).
,, junceum (*Fleming*), p. 406 (6 specimens).
,, portlocki (*Bronn*), p. 406 (17 specimens).
,, maccoyanum *Edwards & Haime*, p. 406 (2 specimens).
,, martini *Edwards & Haime*, p. 406 (4 specimens).
Diphyphyllum *aff.* lateseptatum *M'Coy*, p. 406 (23 specimens).
Syringopora reticulata *Goldfuss*, p. 407 (11 specimens).
,, *cf.* ramulosa *Goldfuss*, p. 407 (9 specimens).
,, catenata (*Martin*), p. 407 (2 specimens).

Brachiopods

By Miss H. M. Muir-Wood, M.Sc., F.G.S.

Productus giganteus (*Martin*), p. 407 (6 specimens).
,, sp. nov. i, [*aff.* giganteus (*Martin*)], p. 407 (5 specimens).
,, sp. nov. ii, [*aff.* giganteus (*Martin*)], p. 407 (5 specimens).
,, striatus *Fischer de Waldheim*, p. 407 (5 specimens).
,, *aff.* auritus *Phillips*, p. 407 (3 specimens).
,, hemisphericus *J. Sowerby*, p. 407 (8 specimens).
,, latissimus *J. Sowerby*, p. 408 (21 specimens).
,, sp. nov. iii, [*aff.* latissimus *J. Sowerby*], p. 408 (8 specimens).
,, sulcatus ? *J. de C. Sowerby*, p. 408.
,, redesdalensis ? *Muir-Wood*, p. 408 (2 specimens).
Pustula elegans (*M'Coy*), p. 408.

The Flora

By Mr. John Walton, M.A., F.G.S.

Rhodea sp., text-fig. 4, p. 409.
Cf. Stigmaria (*rootlets*), p. 410.
Knorria sp. (? Lepidodendron), p. 410.
? Telangium (*rachises*), p. 410.

In the Annals and Magazine of Natural History, Volume I, Tenth Series

Spirifer pennystonensis *sp. n., from the Coal Measures of Coalbrookdale.*

By Mr. T. Neville George, M.Sc.

Spirifer pennystonensis *George*, pl. iv, figs. 1a, b, p. 109.

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IN THE MEMOIRS AND PROCEEDINGS OF THE MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY, VOLUME LXXII

XIII.—*On* Beyrichia kloedeni *M'Coy*

By MR. S. H. STRAW, M.Sc., F.G.S.

Beyrichia kloedeni *M'Coy*, pl. i, figs. 7, 8, p. 197.

IN TYPE AMMONITES, VOLUME VII

By MR. S. S. BUCKMAN, F.G.S.

Anguidactylites anguiformis *S. Buckman*, pl. dcclxii, figs. 1-3.
Harpoceras falciferum (*J. Sowerby*), pl. dcclxiv A, figs. 1, 2.
Phaularpites exiguus *S. Buckman*, pl. dcclxxv B, figs. 1, 2, p. 13.
Toxodactylites toxophorus *S. Buckman*, pl. dcclxxvi, figs. 1, 2.
Spinicoeloceras spicatum *S. Buckman*, pl. dcclxxvii, figs. 1, 1a, 2.
Peridactylites consimilis *S. Buckman*, pl. dcclxxviii, figs. 1, 2.
Parvidactylites parvus *S. Buckman*, pl. dcclxxix (2 views).
Multicoeloceras multum *S. Buckman*, pl. dcclxxxv, figs. 1, 1a, 2.

IN THE NATURALIST

The Genus Fayolia

By DR. R. CROOKALL, F.L.S.

Fayolia crenulata *Moysey*, pl. viii, figs. 2, 3, p. 332 (6 specimens).
,, moyseyi *Pruvost*, pl. viii, fig. 4, p. 361 (2 specimens).

Tylonautilus nodiferus *gen. nov.*=Nautilus (Discites) nodiferus *Armstrong*: *A Carboniferous Guide Fossil*

By MR. J. PRINGLE, F.G.S. and MR. J. WILFRID JACKSON, M.Sc., F.G.S.

Tylonautilus nodiferus (*Armstrong*), pl. xi (2 views), p. 373.

IN BRITISH MUSEUM (NATURAL HISTORY)—CATALOGUE OF FOSSIL CIRRIPEDIA, VOLUME I

Triassic and Jurassic

By MR. T. H. WITHERS, F.G.S.

Eolepas aalensis (*Richardson*), pl. i, figs. 12, 13, p. 70 (5 specimens).
,, oolitica (*J. Buckman*), p. 73 (4 specimens).
Zeugmatolepas concinna (*Morris*), pl. vii, fig. 2; pl. ix, fig. 3, p. 99.

IN MEMOIRS OF THE GEOLOGICAL SURVEY. SUMMARY OF PROGRESS OF THE GEOLOGICAL SURVEY OF GREAT BRITAIN AND THE MUSEUM OF PRACTICAL GEOLOGY FOR THE YEAR 1927, Part ii

XIII.—*Palaeozoic species of* Vetacapsula *and* Palaeoxyris

By DR. R. CROOKALL, F.L.S.

Vetacapsula cooperi *Mackie*, pl. i, fig. 4, p. 91 (2 specimens).
,, moyseyi *Crookall*, pl. i, fig. 6, p. 92.
Palaeoxyris pringlei *Crookall*, pl. ii, fig. 2, p. 103.
,, helicteroides (*Morris*), p. 98 (2 specimens).
,, carbonaria *Schimper*, p. 99 (2 specimens).
,, sp., p. 89.

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In Memoirs of the Geological Survey of Great Britain; Palaeontology—Volume I. (Part 5)

Plectambonites and Some Allied Genera

By Professor O. T. Jones, M.A., D.Sc., F.R.S.

Chonetes minima (*J. de C. Sowerby*), p. 389.
" Strophomena " fletcheri (*Davidson*), p. 389.
Sowerbyella sericea (*J. de C. Sowerby*), pl. xxi, figs. 1-4, p. 414 (8 specimens).
,, ,, *var.* soudleyensis *Jones*, pl. xxi, figs. 5, 6, p. 417 (3 specimens).
,, antiqua *Jones*, pl. xxi, figs. 7-11, p. 419 (5 specimens).
,, sladensis *Jones*, pl. xxi, figs. 14-17, p. 421 (8 specimens).
,, ,, *var.* simulans *Jones*, pl. xxi, figs. 18-20, p. 423.
,, thraivensis (*Reed*), pl. xxi, figs. 21-23, p. 425.
,, *cf.* rhombica (*M'Coy*), pl. xxii, fig. 2, p. 429 (4 specimens).
,, rhombica, *var.* conspicua (*Reed*), pl. xxii, figs. 3-5, p. 430 (7 specimens).
,, duplicata (*J. de C. Sowerby*), pl. xxii, figs. 6-13; pl. xxiii, figs. 1, 2, p. 432 (10 specimens).
,, precursor *Jones*, pl. xxiii, figs. 3-5, p. 437 (3 specimens).
,, *cf.* precursor *Jones*, p. 404.
,, mullochensis (*Reed*), pl. xxiii, figs. 6-8, p. 439 (6 specimens).
,, mullochensis (*Reed*), *var.*? pl. xxiii, fig. 9, p. 441 (3 specimens).
,, superstes *Jones*, pl. xxiii, figs. 10-12, p. 441.
,, penkillensis (*Reed*), p. 443 (3 specimens).
,, millinensis *Jones*, pl. xxiii, figs. 13-16, p. 444 (4 specimens).
,, ,, *var.* canastonensis *Jones*, pl. xxiii, figs. 17, 21, 22, p. 447.
,, ,, *var.* parabola *Jones*, pl. xxiii, figs. 18-20, p. 446 (6 specimens).
,, transversalis (*Davidson*), pars [*Wahlenberg*?], pl. xxiii, fig. 23; pl. xxiv, fig. 1, p. 448 (8 specimens).
,, ,, *var.* lata *Jones*, pl. xxiv, fig. 2, p. 450 (8 specimens).
,, duvali (*Davidson*), p. 452 (26 specimens).
,, undulata (*Salter*), pl. xxiv, figs. 4-6, p. 452 (6 specimens).
,, ,, *var.* maccoyi *Jones*, p. 458.
,, ,, *var.* tricostata (*Reed*), pl. xxiv, figs. 8, 9, p. 458 (5 specimens).
,, plicata *Jones*, pl. xxiv, figs. 10, 11, p. 459 (5 specimens).
,, compressa *Jones*, pl. xxiv, figs. 12, 13, p. 460 (3 specimens).
,, subcorrugatella (*Reed*), pl. xxiv, figs. 14, 15, p. 463.
,, quinquecostata (*M'Coy*), emend *Jones*, pl. xxiv, figs. 16-20, p. 464 (12 specimens).
,, gracilis *Jones*, pl. xxiv, figs. 21-25, p. 472 (6 specimens).
Sowerbyella ? youngiana (*Davidson*), p. 495.
Leptelloidea leptelloides (*Bekker*), pl. xxiv, fig. 26; pl. xxv, figs. 1, 2, p. 475.
,, llandeiloensis (*Davidson*), p. 478.
,, scissa (*Davidson*), pars, pl. xxv, figs. 8-11, p. 481 (8 specimens).
,, segmentum (*Lindström*), pl. xxv, figs. 13-18, p. 485 (6 specimens).
,, sholeshookensis *Jones*, pl. xxv, fig. 19, p. 488 (4 specimens).
,, ruralis (*Reed*), pp. 491, 492 (10 specimens).

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Chonetoidea garthensis *Jones*, pl. xxv, figs. 25, 26, p. 500.
Chonetoidea ? sp. 1, p. 501 (2 specimens).
Chonetoidea sp. 3, p. 502 (2 specimens).

In Memoirs of the Geological Survey of Great Britain; Palaeontology—Volume III. (Part 1)

The British Carboniferous Producti

II.—Productus (sensu stricto); Semireticulatus *and* Longispinus *Groups*

By Miss H. M. Muir-Wood, M.Sc.

Productus productus (*Martin*), pl. i, figs. 1 (4 views), 5, 6, p. 39 (19 specimens).
,, ,, *var.* hispidus *Muir-Wood*, p. 48 (5 specimens).
,, insculptus *Muir-Wood*, pl. iii, fig. 10 (2 views), p. 89.
,, pinguis *Muir-Wood*, pl. v, fig. 1, p. 104 (2 specimens).
,, multispiniferus *Muir-Wood*, pl. viii, fig. 2, p. 121 (4 specimens).
,, pugilis *Phillips*, pl. ix, fig. 1 (2 views), p. 133 (16 specimens).
,, sulcatus *J. Sowerby*, pl. x, figs. 4, 5 (2 views), p. 147 (22 specimens).
,, triquetrus *Muir-Wood*, pl. xi, fig. 7 (3 views); pl. xii, fig. 18 (3 views), p. 163 (7 specimens).
,, concinnus *J. Sowerby*, pp. 52, 53 (19 specimens).
,, carbonarius *de Koninck*, pp. 58, 59 (8 specimens).
,, redesdalensis *Muir-Wood*, p. 63 (3 specimens).
,, vaughani *Muir-Wood*, pp. 68, 69 (2 specimens).
,, griffithianus *de Koninck*, p. 75 (2 specimens).
,, muricatus *Phillips*, p. 81 (3 specimens).
,, furcatus *Muir-Wood*, p. 87.
,, semireticulatus (*Martin*), p. 96 (6 specimens).
,, projectus *Muir-Wood*, pp. 102, 103 (2 specimens).
,, hindi *Muir-Wood*, p. 111 (4 specimens).
,, antiquatus *J. Sowerby*, p. 117.
,, longispinus *J. Sowerby*, p. 159 (4 specimens).
,, tissingtonensis *Sibly*, p. 169 (18 specimens).
,, derbiensis *Muir-Wood*, pp. 172, 173 (3 specimens).
,, lobatus *J. Sowerby*, p. 176 (4 specimens).
,, ,, *var.* laqueatus *Muir-Wood*, p. 179.
,, setosus *Phillips*, pp. 186, 187 (34 specimens).
,, minutus *Muir-Wood*, p. 196 (4 specimens).
Buxtonia sp., pl. xii, fig. 20, p. 36.

In Stratigraphical Palaeontology, A Manual for Students and Field Geologists

By Dr. E. Neaverson, F.G.S.

Orthis calligramma *Dalman*
,, lunata *J. de C. Sowerby*
Bilobites biloba (*Linné*)
Nicolella actoniae (*J. de C. Sowerby*)
Dinorthis flabellulum (*J. de C. Sowerby*)
Heterorthis alternata (*J. de C. Sowerby*)
Harknessella vespertilio (*J. de C. Sowerby*)
Hebertella crispa (*M'Coy*)
Dalmanella elegantula (*Dalman*)
} text-fig. 27, p. 212.

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Conchidium knighti (*J. Sowerby*)
Barrandella globosa (*J. de C. Sowerby*)
,, undata (*J. de C. Sowerby*)
Pentamerus oblongus (*J. de C. Sowerby*)
Stricklandinia lens (*J. de C. Sowerby*)
} text-fig. 29, p. 231.

Leptaena rhomboidalis (*Wilckens*)
Christiania tenuicincta (*M'Coy*)
Triplecia (Cliftonia) spiriferoides (*M'Coy*)
Strophomena expansa (*J. de C. Sowerby*)
Plectambonites sericea (*J. de C. Sowerby*)
} text-fig. 30, p. 234.

Staurocephalus globiceps (*Portlock*), text-fig. 31, p. 237.

Pugnax acuminatus (*Martin*)
Camarotoechia borealis (*Schlotheim*)
} text-fig. 33, p. 257.

Athyris expansa (*Phillips*)
Composita ambigua (*J. Sowerby*)
Spirifer pinguis *J. Sowerby*
Cyrtia exporrecta *Wahlenberg*
Meristina tumida (*Dalman*)
} text-fig. 34, p. 260.

Productus latissimus *J. Sowerby*, text-fig. 35, p. 268.

Anisoloboceras nautiliforme (*J. Buckman*), text-fig. 42, p. 335.

Strigoceras truelli (*d'Orbigny*)
Chondroceras delphinus *S. Buckman*
Teloceras labrum *S. Buckman*
} text-fig. 46, p. 352.

Cosmoceras acutistriatum *Robson*, text-fig. 49, p. 363.

Trigonia caudata *Agassiz*
,, clavellata *J. Sowerby*
,, costata *J. Sowerby*
,, duplicata *J. Sowerby*
,, gibbosa *J. Sowerby*
,, nodosa *J. de C. Sowerby*
,, v-costata *Lycett*
} text-fig. 52, p. 369.

Ringsteadia pseudocordatus (*Blake & Hudleston*)
Prionodoceras superstes (*Phillips*)
Cardioceras quadrarium *S. Buckman*
} text-fig. 54, p. 375.

Turrilites wiesti *Sharpe*, text-fig. 59, p. 406.

Neithea quinquecostatus (*J. Sowerby*), text-fig. 62, p. 417.

B. Scotland

The Old Red Sandstone of the Orkney Islands has yielded a fine suite of fossil fishes and plants. The fishes have been submitted to Professor D. M. S. Watson, F.R.S., and the plants to Professor W. H. Lang, F.R.S., and results of importance are likely to be obtained from the study of these materials. Professor Watson has furnished the following preliminary note on the fish remains :—

' Large collections of Old Red Sandstone fishes have been made from the West Mainland, from Deerness, South Ronaldshay, Sanday, and Eday. The collections from the Rousay and Eday Beds consist largely of the remains of Dipnoan fish, a condition in striking contrast to that which exists in the Stromness Beds and their equivalents in the Moray Firth region.

' The extensive collections made during the last two seasons in Orkney confirm the late Dr. Traquair's faunal separation of the Stromness, Rousay and Eday Beds, whilst adding some new forms.

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There is now evidence of the association of a small square-scaled Osteolepid with *Tristichopterus* in the Eday Beds of South Ronaldshay, unfortunately represented by undeterminable fragments.

'The large Coccostean to which I referred in last year's *Summary of Progress* has now been found 875 yards W.41°N. of Warsetter Farm, Sanday, in association with *Tristichopterus* and *Pentlandia* in the Eday Beds. It is also known from Inganess Farm, Kirkwall, in Rousay Beds (?), and from Newark Bay, Deerness, in what are assumed to be Eday Beds. It is thus probable that it is restricted to a narrow belt of rocks.

'A small *Dipterus*, which is exceedingly abundant on the shore 460 yards east of Horraquoy, Deerness, cannot be definitely distinguished from *Dipterus valenciennesi*, but it is usually much smaller, and has so characteristic an appearance that it may in the future be possible to differentiate it. It presumably belongs to a horizon near the summit of the Rousay Beds.'

While no specimens of outstanding interest have been obtained during visits to the numerous borings in Carboniferous rocks, the fossils have proved to be of the utmost value in establishing the sequence of the rocks passed through, and in some instances they have helped to elucidate the stratigraphical relations of certain limestones in districts where good natural exposures are not available.

The discovery of '*Edmondia*' *punctatella* (Jones) in the Douglas Coalfield is worthy of special note. Specimens of this interesting shell were found in the bed of Kennox Water at a point 700 yards E.23°S. of Chapel Hill. This species is an index to the position of the Calmy Limestone, and as the shell has been traced over a great part of Central Scotland, it has a stratigraphical value of considerable importance. '*E.*' *punctatella* is itself of some biological interest. The shell was formerly regarded as belonging to the Eucrustacea, but was afterwards placed among the Mollusca by T. R. Jones. Later, W. Hind described it under the name *Edmondia punctatella*; but a close study of the specimens tends to confirm the opinion of the late Dr. G. W. Lee that a new generic name is required. It may be pointed out that *Edmondia* is a definitely marine shell, whereas '*E.*' *punctatella* is estuarine.

F. L. KITCHIN.

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2.—PALAEOBOTANICAL WORK

The chief item of work during the year has consisted in the examination and identification of fossil plants sent in from the following one-inch sheets: 8, 15, 23, 32, 75, 85, 109, 110, 152, 230, 231 (England), and 14, 22, 30, 31, 39 (Scotland), while fossils from the Bristol and Derbyshire Coalfields have been identified for outside workers.

Dr. Crookall has prepared a catalogue of the 4,000 photographic negatives in the Kidston Bequest, with details as to the collection and number of the fossil, size of plate, multiplication, details shown, if and where figured, etc. Most of the photographs are of impressions in the Kidston Collection, but there are also numerous negatives of fossils in most of the British museums, as well as of specimens in private collections. Negatives of micro-sections in the Scott and other collections are also present.

With considerable assistance on the stratigraphical side from Mr. E. B. Bailey, an account of the flora of the Coal Measures of Ayrshire has been written, this being incorporated in the North Ayrshire Memoir, now in the press. Dr. Crookall has also revised the palaeobotanical section for the Huddersfield Memoir, prepared by Mr. C. E. N. Bromehead.

General assistance has been given in checking the lists of plants appearing in the various Sheet memoirs issued during the year, and those at present passing through the press, while many enquiries have been answered and assistance given to research workers and others.

An account of the stratigraphical distribution of the 584 known species of British Coal Measures plants has been drawn up, and their application as zonal indices reviewed, while similar treatments of the Lower Carboniferous flora and of the British Carboniferous petrifactions are in course of preparation.

In continuance of critical studies of *Vetacapsula*, *Palaeoxyris* and *Fayolia* a new species of the last named genus has been described, and the genus reviewed.

The following specimens in the Kidston and palaeobotanical collections have been figured, described or mentioned in publications:—

IN THE SUMMARY OF PROGRESS OF THE GEOLOGICAL SURVEY FOR 1927, PART II

(published 1928)

XIII.—*Palaeozoic species of* Vetacapsula *and* Palaeoxyris

By R. CROOKALL, PH.D.

Vetacapsula johnsoni (*Kidston*), pl. i, fig. 5, p. 93 (No. K. 908).
,, kidstoni *Crookall*, pl. i, figs. 7, 8, p. 95 (Nos. R.C. 245, 248).
Palaeoxyris edwardsi *Crookall*, pl. ii, fig. 3, p. 103 (No. R.C. 255).
,, warei *Crookall*, pl. ii, fig. 6, p. 102 (No. R.C. 256).

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? Palaeoxyris sp., pl. ii, fig. 5, p. 104 (No. R.C. 252).
Specimens mentioned, viz. :—
Vetacapsula moyseyi *Crookall*, p. 93 (No. K. 6994).
,, johnsoni (*Kidston*), p. 94 (No. K. 191).
,, kidstoni *Crookall*, p. 95 (Nos. R.C. 246, 247).
Palaeoxyris helicteroides (*Morris*), p. 99 (Nos. K. 593, 4153, 6976-6981).
,, carbonaria *Schimper*, p. 100 (Nos. K. 6973-6975).
,, prendeli *Lesqx.*, p. 101 (Nos. 190, 192, 4151).

IN 'THE NATURALIST' FOR NOVEMBER AND DECEMBER, 1928, p. 325

The Genus Fayolia

By R. CROOKALL, Ph.D.

Fayolia warei *Crookall*, pl. viii, fig. 1, p. 362 (No. R.C. 253).
Specimens mentioned, viz. :—
Fayolia crenulata *Moysey*, p. 332 (Nos. K. 4149, 4150).

IN STRATIGRAPHICAL PALAEONTOLOGY, A MANUAL FOR STUDENTS AND FIELD GEOLOGISTS, 1928

By E. NEAVERSON, D.Sc.

Sphenophyllum emarginatum *Brongt.*, text-fig. 40, p. 298 (No. K. 2302).
Neuropteris macrophylla *Brongt.*, text-fig. 40, p. 298 (No. K. 290).
Dactylotheca plumosa (*Artis*), text-fig. 40, p. 298 (Nos. K. 2107, 2111).
Renaultia gracilis (*Brongt.*), text-fig. 40, p. 298 (No. K. 775).
Zeilleria delicatula (*Sternb.*), text-fig. 40, p. 298 (No. K. 204).
Telangium affinis (*L. & H.*), text-fig. 40, p. 298 (No. K. 644).

R. CROOKALL.

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3.—PETROGRAPHICAL WORK

Petrographical work has been, apart from routine duties in the Department, mainly in connexion with the forthcoming memoirs on Ardnamurchan and Coll in Scotland and the Cheviot region in England. Work has also been carried out in relation to other districts in progress of surveying.

The petrology of the Tertiary rocks of Ardnamurchan has been entirely in the hands of the Petrographer, but Mr. Bailey has undertaken the descriptive petrology of the older rocks of Coll and the mainland. Frequent references have been made to the petrology of Ardnamurchan in the *Summaries of Progress* for past years and the publication of full details in the immediate future renders unnecessary any further discussion of the subject in this place. It may be said, however, that Ardnamurchan exemplifies in simple yet striking manner the phenomena of ring-dyke intrusion, and presents many new facts that are of considerable importance in relation to magmatic differentiation and petrogenesis. The range of rock-types is fairly large, and fresh light is thrown upon the form and mechanics of their intrusion. The idea of magma-types enunciated for Mull has been developed, while an endeavour has been made to trace their genetic connexions and account for their differences. Hybridization is considered to play some part in the genesis of certain rock types and structures, and is held to be responsible for the tonalitic and monzonitic types that occupy the centre of the latest complex. The fact that Ardnamurchan is the last remaining important area of Tertiary igneous rocks to be dealt with has impressed the authors of the memoirs with the desirability of reviewing, if space permits, the subject of Tertiary igneous activity in Britain in the light of the most recent work.

In other fields Mr. A. G. MacGregor has completed a detailed study of the lavas of Carboniferous and Old Red Sandstone age in Ayrshire, the results of which will be found embodied in the memoir on North Ayrshire, now in the press.

Dr. H. H. Read has engaged in a comparative study of the Lewisian rocks of the north-west of Scotland and has made full use of the mass of material collected by the earlier surveyors, and preserved in our collections.

HERBERT H. THOMAS.

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4.—CHEMICAL WORK

During 1928 the quantitative analyses completed were mainly for the Scottish Memoirs and include the following :—

858. *Epidiorite.* Boss in Moine Series. 160 yds. W. of Loch a'Mhoid. 6-inch map, Sutherland, 43 S.E. Slice No. S. 25690.

859. *Serpentine.* Mass in Moine Series. Allt Diona-Choire, 1 mile W. of north end of Loch na Bruthaiste. 6-inch map, Sutherland, 43 N.E. Slice No. S. 25691.

860. *Pulaskite.* Part of Loyal 'Granite.' S.W. slope of Cnoc Arach nan Cuilean, 1⅛ miles N.10°W. of Innisceananlocha. 6-inch map, Sutherland, 35 S.W. Slice No. S. 25692.

861. *Scyelite* (altered). Boss in Moine Series. Shore of Loch Shin, at foot of path from Overscaig Inn. 6-inch map, Sutherland, 73 N.W. Slice No. S. 25693.

878. *Cordierite-diaspore-hornfels.* Contact-altered Greenstone. Inner Quarry, Kenidjack, near St. Just. 6-inch map, Cornwall, 67 S.W. Slice No. E. 14058.

879. *Bostonite.* Dyke. The Haven, Swona, Orkney. 1-inch map, Scot., 117. Slice No. S. 25818.

Lab. Nos.	858	859	860	861	878	879
SiO_2 ...	50·02	37·53	63·33	43·56	33·58	60·69
Al_2O_3 ...	15·36	0·72	16·98	3·06	11·79	20·91
Fe_2O_3 ...	2·29	5·12	1·41	3·59	11·27	1·61
FeO ...	8·08	1·78	1·14	3·80	17·50	0·09
MgO ...	7·76	37·99	1·17	31·32	15·55	0·09
CaO ...	8·81	1·32	2·58	3·57	0·89	0·12
Na_2O ...	2·94	0·18	6·06	0·29	0·60	1·66
K_2O ...	1·30	0·03	5·90	1·31	0·32	11·34
$H_2O>105°C.$	1·01	11·75	0·18	7·04	4·60	2·67
$H_2O<105°C.$	0·16	0·68	0·14	0·14	0·13	0·52
TiO_2 ...	1·80	0·09	0·53	0·37	2·96	0·16
P_2O_5 ...	0·14	0·00?	0·24	0·02	0·36	0·07
MnO ...	0·18	0·17	0·10	0·19	0·21	0·02
CO_2 ...	0·12	2·04	0·00?	1·31	0·00	0·00
Cl	—	—	—	—	0·02	0·00
F	0·00?	0·00	0·00?	0·00	0·00	0·00
FeS_2 ...	0·19	0·29	0·14	0·32	—	—
Fe_7S_8 ...	0·00?	0·00?	0·00	0·00	—	—
Cr_2O_3 ...	0·00?	0·33	0·00?	0·25	0·00	0·00
NiO, CoO ...	0·00	0·08	0·00	0·02	0·00	0·00
BaO ...	0·00	0·00	0·34	0·00	—	—
Li_2O ...	0·00	0·00	0·00?	0·00	0·00	0·00?
Totals ...	100·16	100·10	100·24	100·16	99·78	99·95
Analysed by	B. E. Dixon				R. Sutcliffe	

868. *Teschenite* with some biotite; olivine completely serpentinised; felsic minerals somewhat altered, as is usual in teschenites. Sill cutting underlying quartz-dolerite of Craigens Sill Complex. Probably Permian. Railway cutting, 100 yards W.N.W. of Sykeside, barely 1½ miles E.S.E. of Town Hall, Cumnock. 6-inch map, Ayr, 35 S.E. Slice Nos. S. 25771 and S. 25529.

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869. *Olivine-free Camptonitic Hornblende-teschenite*, allied to lugarite; felsic minerals much altered. Sill, probably Permian. Glaisnock Hill, 1,000 yards S.15°W. of Over Glaisnock, 2 miles S.18°E. of Cumnock. 6-inch map, Ayr, 41 N.E. Slice Nos. S. 25772 and S. 25512.

870. *Picrite*. (Abundant olivine, mostly fresh; some biotite; sparse felsic minerals much altered.) Ultra-basic facies of theralitic essexite of Kyle type. Picrite facies of kylite sill, probably Permian. Craigdonkey, Beuquhat Hill, 900 yards N.N.E. of school, Beuquhat. 6-inch map, Ayr, 46 N.E. Slice Nos. S. 25773 and S. 25515.

871. *Non-ophitic Essexitic Olivine-dolerite*. (Fresh rock.) Closely allied to the less mafic theralitic essexites of Kyle type. Outer part of composite intrusion, cutting Cementstone Series. Probably Permian. Elongated hill, 550 yards W.40°S. of Carskeoch, 1 mile S. of Patna. 6-inch map, Ayr, 46 N.W. Slice Nos. S. 25774 and S. 25518.

872. *Monchiquitic Olivine-basalt*. (Fresh rock but analcite cloudy.) Dyke cutting ash neck (probably Permian in age), which cuts Carboniferous Limestone Series. Patna Hill, 1,130 yards W.9°S. of Downieston, Patna. 6-inch map, Ayr, 46 N.W. Slice Nos. S. 25775 and S. 25521.

873. *Theralitic Essexite* of Crawfordjohn Type. (Fresh except for alteration of felspathoid minerals.) Intrusion in ash neck (probably Permian in age), which cuts strata near base of Cementstone Series. Carclout Hill, quarry beside wall, 1¼ miles W.S.W. of Patna. 6-inch map, Ayr, 45 N.E. Slice Nos. S. 25776 and S. 25522.

Lab. Nos.	868	869	870	871	872	873
SiO_2 ...	47·97	45·13	43·15	48·30	45·13	46·64
Al_2O_3 ...	14·87	14·78	8·67	16·34	13·07	17·68
Fe_2O_3 ...	2·81	4·61	2·86	0·82	2·55	1·79
FeO ...	6·93	5·74	9·83	9·31	7·97	8·17
MgO ...	5·55	5·69	20·70	6·74	12·65	5·98
CaO ...	8·27	10·59	7·16	10·59	10·18	11·69
Na_2O ...	3·81	3·76	1·66	2·91	2·32	3·06
K_2O ...	2·31	2·37	0·73	1·13	1·12	1·34
$H_2O > 105°C.$	4·26	3·41	3·86	1·02	2·44	1·44
$H_2O < 105°C.$	0·67	0·37	0·26	0·10	0·17	0·06
TiO_2 ...	2·09	2·72	0·92	2·07	1·57	1·61
P_2O_5 ...	0·27	0·55	0·29	0·34	0·49	0·42
MnO ...	0·43	0·26	0·33	0·29	0·38	0·39
CO_2 ...	0·05	0·32	0·16	0·07	0·02	0·00
Cl	0·00	0·01	0·01	0·00	0·00	0·01
F	0·00	0·03	0·00	0·02	0·03	0·00
FeS_2 ...	0·00	0·00	0·00	0·00	0·00	0·03
NiO, CoO ...	0·00	0·03	0·03	0·02	0·03	0·02
BaO ...	0·00	0·01	0·00	0·00	0·02	0·01
Li_2O ...	0·00?	0·00?	0·00	0·00	0·00	0·00
Less O for F	—	0·01	—	—	0·01	—
Totals ...	100·29	100·37	100·62	100·07	100·13	100·34
Analysed by	E. G. Radley.					

B. E. Dixon.

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IV. MUSEUM OF PRACTICAL GEOLOGY

Museum work continues to be hampered by the state of the building, and pending the removal to South Kensington improvements and rearrangements of the displayed material cannot be undertaken. The total number of visitors during the year was 20,287, of which 1,409 were Sunday visitors. Twenty-six demonstrations were given to schools and institutions, the aggregate attendance being 434.

Special exhibits were prepared for the conference of Empire Surveyors who visited the museum in July, for the Geologists' Association, for the Yorkshire Geological Society Exhibition at Leeds and for the Technical Institute at Folkestone. Certain cases have been cleaned and rearranged and special exhibits illustrating, amongst other things, the Wabana Iron Ore, the occurrence and association of Burmese Jadeite, and Geological Survey Maps published in 1928, are now displayed.

Registration of material and cataloguing of the collections has been carried on steadily; 1,588 specimens of the Lindsey Collection and 308 specimens of the Ludlam Collection were numbered, registered and card-indexed; a card index of Scottish geological photographs was begun and 950 cards completed by the end of the year. The revision of the Catalogue of Instruments was undertaken. A new catalogue was prepared, checked and substantial progress made with arrears of engraving.

In the absence in the field of the photographer, the museum staff supplied to the order of the public 154 lantern slides and 106 prints of Geological Survey photographs. A certain amount of field collecting and photography was also completed, and 60 rock sections were prepared.

For a considerable part of the year the Curator was engaged in geophysical work in the field with the Eötvös Torsion Balance. The results of one of the surveys are now in the press, whilst the necessary field work for another survey has been completed. In the course of this work training in the method was given to officers of the Australian and Canadian Governments.

The additions to the library during the past year comprise 261 volumes of independent works, 3,233 volumes and parts of serials, 207 pamphlets, 475 maps and 262 geological photographs. The Survey Collection of photographs now numbers 8,500, and there has been a growing demand for prints and lantern slides, work which is now executed by the Survey and Museum staffs; 471 lantern slides and prints were supplied to the public. The library continues to be used by students, mining engineers and professional enquirers to an increasing degree.

W. F. P. McLintock.

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Special Reports on the Mineral Resources of Great Britain

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VOL. VII. MINERAL OIL, KIMMERIDGE OIL SHALE, LIGNITES, JETS, CANNEL COALS, NATURAL GAS. ENGLAND and WALES. By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S., with contributions by W. Gibson, D.Sc., H. Dewey, B. Smith, M.A., C. E. N. Bromehead, B.A., and J. Pringle. 125 pp. 1 plate. 7 text-figures. Wrapper ... ... (1918; Edit. 2, 1920)	5	0
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I.—A GRAVITATIONAL SURVEY OVER THE BURIED KELVIN VALLEY AT DRUMRY, NEAR GLASGOW

BY

W. F. P. McLintock, D.Sc., and James Phemister, M.A., D.Sc.

Text-figures 1 to 5.

INTRODUCTION

In this country where so much of the solid geology is obscured by glacial deposits of variable thickness a knowledge of subdrift topography, apart from its scientific interest to glacial geologists, is often of considerable economic importance especially in coalfield areas where the presence of buried channels filled with clay or sand may seriously complicate mining operations. Owing to the fact that the drift is of moderate thickness and usually has a lower specific gravity than the subjacent rock, pronounced irregularities in the rock-surface frequently cause distinct gravitational anomalies readily detectable by the Eötvös Torsion Balance. In fact, in the investigation of geological structure by a torsion balance survey, it may happen that these irregularities produce local gravitational effects sufficiently large to obscure the effects due to the structure, and the disentangling of such local anomalies is a necessary preliminary to a successful geological interpretation of the balance results. It follows that gravitational survey with the torsion balance is an obvious method of mapping subdrift topography and it was decided to put it to a practical test in an area where subdrift irregularities were known from boring and mining evidence and where the surface topography was sufficiently irregular to demand careful evaluation of terrain and topographic corrections.

The buried channel of the River Kelvin, about 7 miles west-north-west of Glasgow, was selected as a test area fulfilling the necessary requirements. The existence of this channel has long been known from an extensive series of borings put down in search of coal and ironstone. The borings proved the presence not only of a deep, drift-filled channel but also of a mass of rock rising abruptly through the drift to 74 ft. from the surface near Drumry. The district is one of moderate relief (see map, Fig. 2), and it was therefore considered that, whilst the corrections for terrain and topography would be large and demand careful evaluation, there would still remain residual gravitational effects sufficiently large to enable the evidence of the subdrift features gained from the borings to be confirmed and, perhaps, extended.

Operations were commenced in November 1927, and continued until March 1928, during which period 68 stations were determined by visual observation at night. A complete account of the work with the relevant mathematical analysis has already appeared[1]

[1] *Trans. Roy. Soc. Edin.*, vol. lvi, part 1 (No. 7), 1929, pp. 141-155.

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but a short resumé of the results is given here in the hope that it may interest geologists in a new method of investigating a difficult and important problem.

THE NATURE OF THE TEST

The map, Fig. 1, reproduced from the Geological Survey Memoir on the Geology of the Glasgow District, shows the contours of the buried rock surface after removal of the superficial deposits in

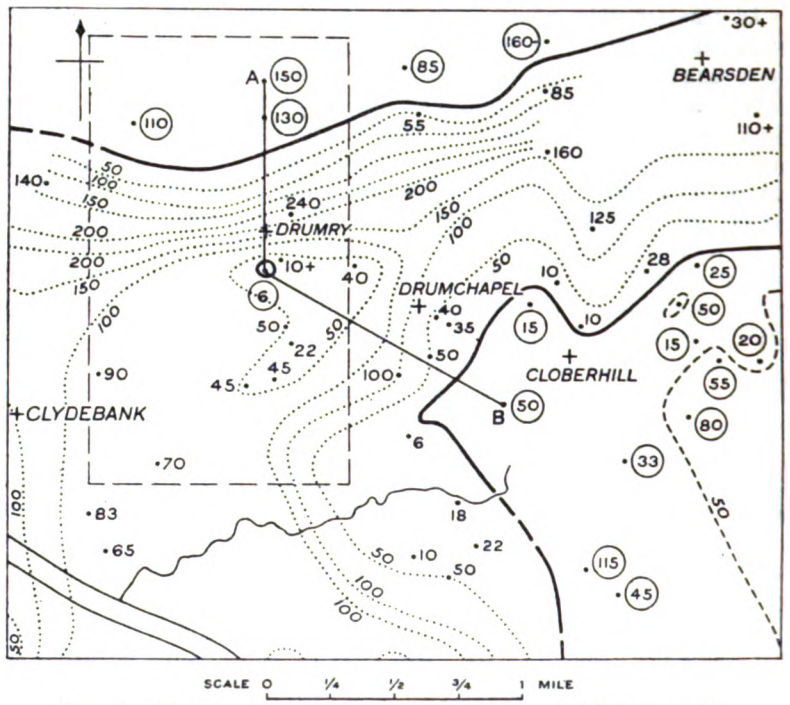

FIG. 1.—*Contour Map of the Rock Surface around Drumry after removal of the superficial deposits.*

·(25) *Height of rock surface in feet above ordnance datum level.*
·25 *Depth ,, ,, below ,, ,,*
·25+ *Depth below O.D. level, rock surface not reached.*
·(25)– *,, above O.D. ,, ,, ,,*
------ *Contours in feet above O.D. level.*
..... *,, ,, below ,,*
— — *Ordnance datum (present mean sea level).*
Inset is the area shown in FIG. 3.

the district around Drumry. The contours are in feet referred to ordnance datum level and are plotted from the data yielded by the borings whose sites are marked on the map. The map clearly shows the deep channel north of Drumry and the steeply sloping mass of

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rock rising through the drift, but nowhere reaching the surface, to the south of that place. The deep channel is shown as extending to the west for a distance of at least one mile, an inference based on one record of the depth of drift obtained from a mine working and indicated on the north-west edge of the figure.

The drift covering these ancient topographic features consists of clays and sands with an average specific gravity at the surface of 1·72 whilst the underlying sandstones, shales, ironstones and

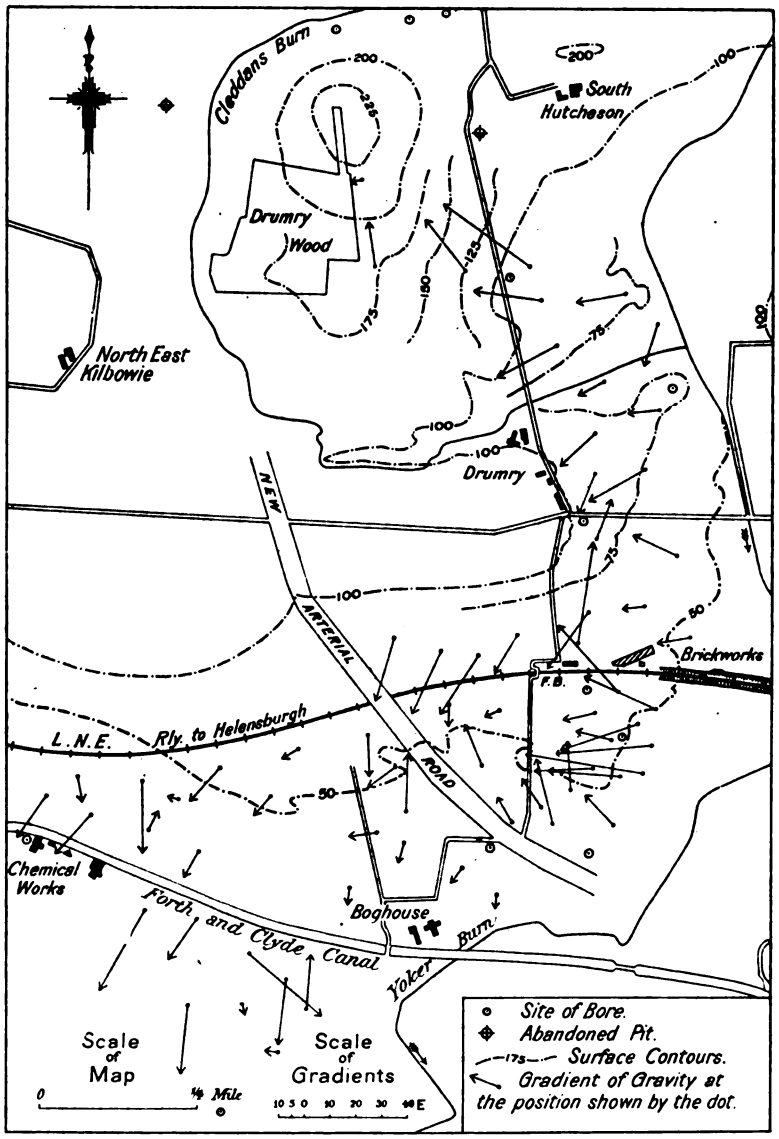

FIG. 2.—*Gradient Map of the Drumry District.*

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coals, belonging to the Coal and Ironstone Group of the Carboniferous Limestone Series, have an average specific gravity of, approximately, 2·38. There is consequently a density difference amply sufficient to render measurable the gravity anomalies arising from the irregularities of the surface between drift and rock. The objects of the survey were to determine the configuration of the rock-mass to the south of Drumry and to investigate the trend of the buried channel to the north by the method of traverse across its inferred strike.

GRAVITATIONAL RESULTS

(1) The Rock-mass South of Drumry.—Fig. 2 shows the gradients of gravity corrected for normal, terrain and topographic effects, with surface contours at intervals of 25 ft. to indicate the type of topography in the areas where topographic corrections were necessary. Fig. 3 shows the gradients and the isogams, *i.e.* lines of equal gravity anomaly, constructed from them, in the most critical part of the area surveyed. The presence of the rock-mass south of Drumry is clearly demonstrated by the consistent group of gradients directed westwards, and the isogams give some idea of its shape and dimensions. An inspection of the results plotted on the two figures shows (*a*) that the rock-mass has a steep eastern face; (*b*) that this face is incised in places; and (*c*) that the rock-mass is a ridge, with an irregular upper surface, extending westwards for a considerable distance.

(*a*) The steep eastern face is qualitatively shown by the large gradients directed westwards and the closely packed parallel isogams which are roughly comparable with the contours of the surface between rock and drift. By graphical and mathematical methods it is possible to calculate the slope of this face and to estimate the depth of its top from the surface. In the lower part of Fig. 4 is shown (1) the experimental curve formed by plotting the values of the average gradients along the line AB, Fig. 3, against the distance; (2) the theoretical curve of gradients, similarly obtained, due to a buried bank with a slope of 10°, as shown in the upper part of the figure; (3) the curve of difference between these two. This difference may be accounted for by assuming that the top of the bank, instead of being horizontal (dotted line) rises gently to the west as a slope of 2½° (continuous line). If now we plot the gradients due to the wedge-shaped mass lying between the continuous and the dotted lines the points shown by circles are obtained. These points practically coincide with the difference curve and hence it may be inferred that the gravitational effects are due to a westward rise of the rock-mass in the manner illustrated in Fig. 4; that is, the surface between rock and drift rises quickly from the east as a slope of 10°, flattens for a short distance and continues to rise more gently westwards as a slope of 2½°.

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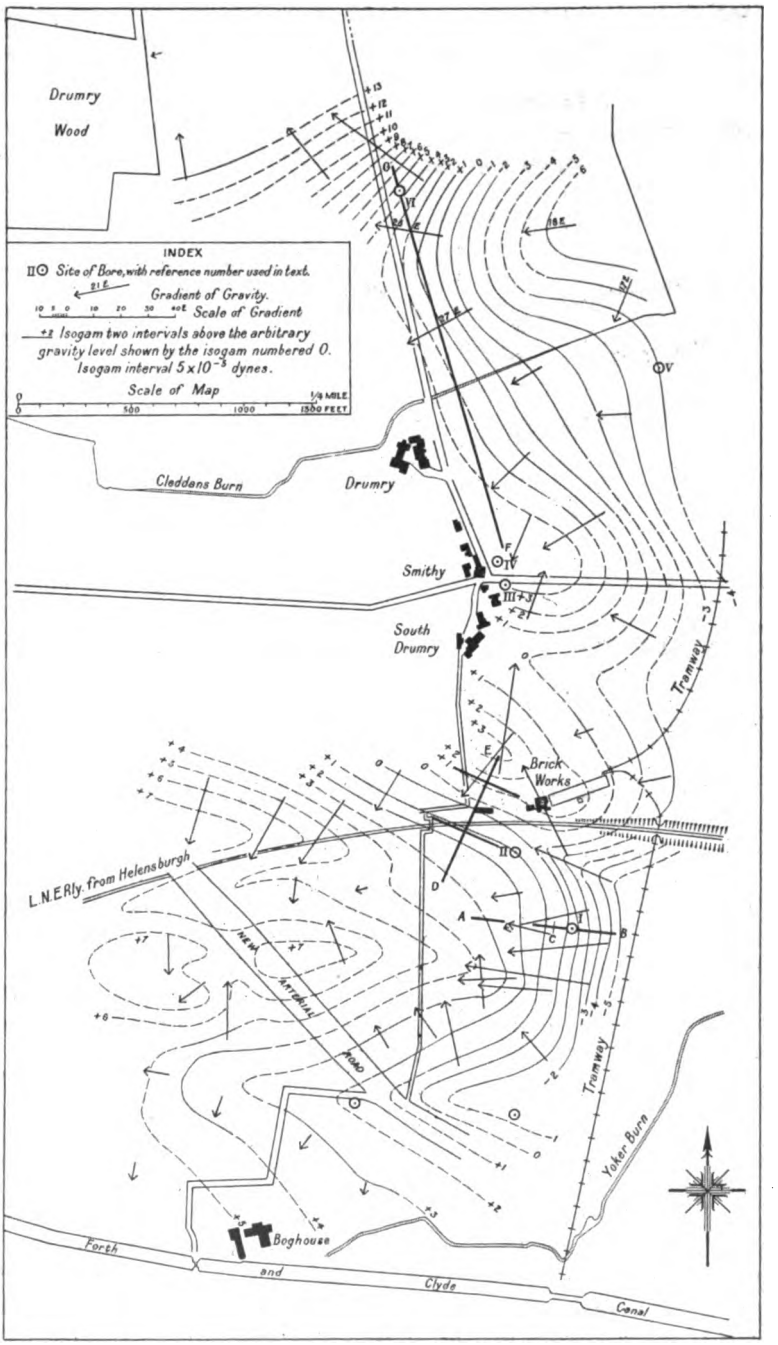

FIG. 3.—*Map showing Gradients and Isogams around Drumry.*

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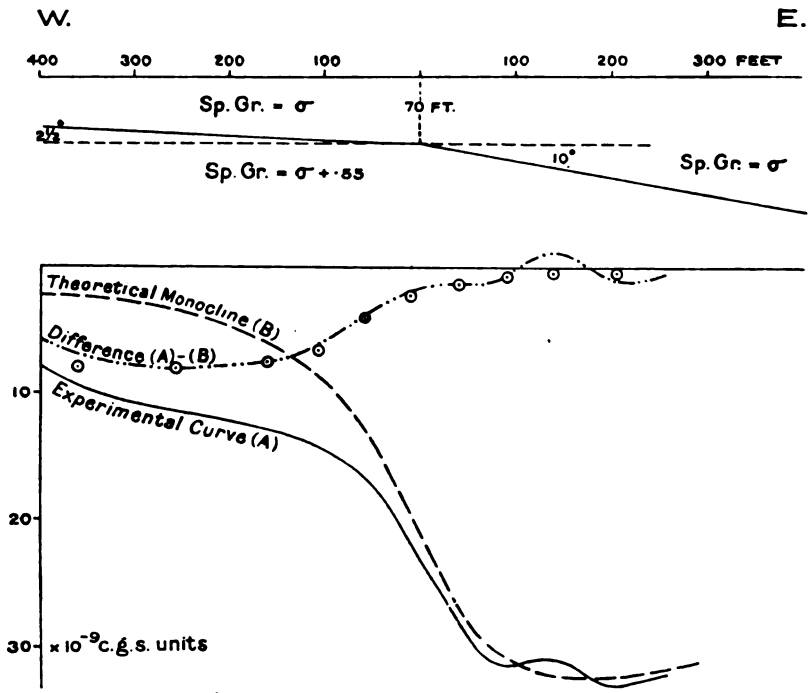

FIG. 4.—*Structure, theoretical and experimental gradients along the line A B of* FIG. 3.

The calculated depth to rock at the point C, Fig. 3, is 70 ft.; the calculated depth to rock at the position of bore I, Fig. 3, is 80 ft.; the bore journal showed rock at 74 ft. These calculations are made on the assumption that the specific gravity difference between rock and drift is ·55. The average specific gravity of Carboniferous rocks of similar type to those recorded in the journal of bore I is 2·38 and thus the specific gravity of the drift calculated from the gravitational results is 1·83; the average of 13 determinations at the surface gave the value 1·72. This difference between the calculated and determined values is doubtless partly due to an increase in the density of the drift at increasing depths.

(*b*) The isogams, Fig. 3, show that the eastern face of the rock-mass is incised in three places, the most marked of these incisions being the one immediately south-west of the brickworks. By methods similar to those mentioned above it can be deduced that a drift-filled hollow exists in the position indicated by the two parallel lines drawn perpendicular to the line DE on the figure. The approximate calculated dimensions of this hollow are, width 200 ft., and possible depth to rock 150 ft. Bore No. I showed rock at a depth of 74 ft. and bore No. II, south-west from the brickworks showed rock at a depth of 114 ft.; the gravitational

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and boring evidence are thus in essential agreement, although the gravitational interpretation of the buried topography is different from that shown on the map, Fig. 1.

(*c*) The westward extension of the rock-mass is shown by the isogams, Fig. 3; they also indicate that there is a gentle but persistent rise to the south and west. As a result of this approach of the rock to the surface small irregularities in the form of local knobs and hollows will cause considerable local variations in gradient both in magnitude and direction. Reference to Fig. 2 shows that such rapidly changing gradients were encountered in the south and west of the area surveyed. For example, to the north of the Chemical Works the gradients indicate a rock knob south of the railway with a hollow on the south succeeded by a rise still farther south towards the canal. At the Chemical Works itself a bore shows 116 ft. of drift. These local heights and hollows may be compared with the deep hollow south-west of the brickworks described above and show clearly that for a thorough investigation of a shallow buried topography a very close network of stations is necessary.

(2) The Buried Channel North of Drumry.—The map, Fig. 1, shows a deep channel north of Drumry continuing westwards for a distance of at least one mile. This western extension is deduced from the evidence of an isolated record of a depth of 140 ft. of drift shown on the extreme western side of the map. From what has been said above regarding the rapid local variations in the buried topography of this district it is clear, therefore, that the inferred western extension of the deep gorge is conjectural and it was decided to test the matter by a north-south traverse across the presumed strike of the channel. The results plotted on Figs. 2 and 3 show that there is no gravitational evidence for the existence of a deep gorge to the west. The magnitude and direction of the gradients and the trend of the isogams indicate clearly that the buried channel does not continue westwards but bends sharply to the south about ½ mile north of Drumry. The consistent westerly trend of the gradients and their magnitude point to the existence of a western bank which appears to be a northern continuation of the rock-mass south of Drumry. This bank stretches to the north of Drumry for approximately ½ mile and there, as shown by the course of the isogams, bends sharply to the east. The boring positions are shown on Fig. 3. Bores III and IV disclosed drift of a thickness of 93 feet and 120 feet respectively, but no rock was reached in either of them. At bore V rock was reached at 298 ft. and at bore VI the depth to rock was 132 ft. The thickness of drift is referred to the surface of the ground at each bore site whose heights above ordnance datum can be obtained from the contoured map, Fig. 2.

A diagrammatic representation of the course of the buried channel on the two hypotheses is given in Fig. 5 (*a*) and (*b*), the

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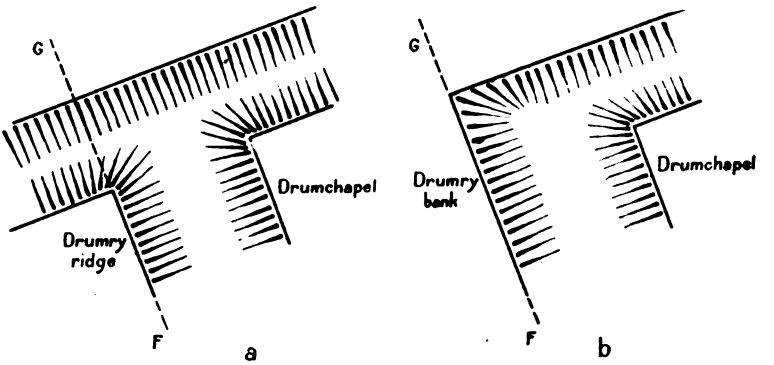

FIG. 5.—(a) *Diagrammatic representation of the buried Kelvin Channels according to the contour map of the rock surface, in the Glasgow Memoir.*

(b) *Diagrammatic representation of the bend in the buried Kelvin Channel according to the gravitational survey.*

line FG in both cases corresponding to the line FG on Fig. 3. If the channel runs as in Figs. 1 and 5 (*a*) then it can be shown that the maximum westerly gradient obtainable in a traverse across the northern channel is approximately 10 E. (=10 Eötvös units = $10 \times 1 \times 10^{-9}$ C.G.S. units). A gradient of 26 E. towards the west was actually measured in the field. By similar calculation it can be shown that on the second hypothesis, the theoretical maximum westerly gradient is approximately 32 E. whilst above bore V, the deepest known part of the channel, the theoretical gradient is 11–12 E.; these values are of the same order as the gradients determined from balance readings in the field. The gravitational evidence is thus definitely against a western extension of the northern channel. Apart from the mathematical analysis given in detail in the paper quoted (p. 1) it is proper to point out that the hollow known from the boring evidence to exist south of the brickworks (see above) was clearly demonstrated by a westward indentation of the isogams; a much more pronounced indentation of the isogams would have shown up the conjectured western extension of the northern channel had it existed. The isogams, however, show no westward indentation but swing sharply to the north and east. The qualitative results therefore point to the representation in Fig. 5 (*b*) as being the correct one and it has been shown that the values of the gradients calculated on that assumption agree with those determined by field measurement.

CONCLUSIONS REGARDING THE VALUE OF THE METHOD

The results described show that gravitational survey by means of the torsion balance is of considerable value for mapping sub-drift topography. The method adopted in the present instance,

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namely, to obtain confirmatory gravitational evidence of the existence of features known from borings and then to extend the survey into the unproved areas, illustrates one of the most useful ways of employing the balance. In many areas in this country our knowledge of subdrift topography is extremely limited and boring is a costly business. If the rock-surface below the drift is highly irregular, the scanty information derived from widely separated isolated borings is by no means sufficient to interpret the topography of that surface with accuracy, and an interpretation based solely on such evidence may, as already shown, prove untenable.

In such cases the gravitational method may be usefully employed to extend and supplement the boring evidence and for this purpose it is both cheaper and quicker than the drill.

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II.—A GRAVITATIONAL SURVEY OVER THE PENTLAND FAULT, NEAR PORTOBELLO, MIDLOTHIAN, SCOTLAND

BY

W. F. P. McLintock, D.Sc., and James Phemister, M.A., D.Sc.

Text-figures 1 to 10

INTRODUCTION

The mapping of concealed geological structure by the method of gravitational surveys with the Eötvös Torsion Balance depends on the fact that in most geological structures lighter and heavier rocks are brought into juxtaposition in such a way that the surface of separation between the two is inclined to the horizontal. Previous tests with the torsion balance have been carried out by the Geological Survey in areas where the nature of the lighter and heavier rocks was already well known from the geology and where the surface of separation was known to be inclined to the horizontal;[1] in the case of the Swynnerton dyke a steeply inclined mass of heavy basalt pierces horizontally bedded Keuper Marl of low specific gravity, whilst at Drumry loose sands and clays overlie a highly irregular pre-Glacial topography carved out of Carboniferous sediments of much higher specific gravity. In both instances it was found possible by means of the balance to determine the positions and boundaries of the concealed heavier rock masses and to calculate depths and slopes.

In areas composed of ordinary sedimentary rocks that have been folded or faulted the older rocks are usually denser than the younger and consequently anticlines and domes show an excess of gravity above their axes, whilst synclines and basins show a deficiency; similarly, in an area intersected by a large fault there is an excess of gravity on the upthrow side, that is, the side on which the older rocks are brought nearer the surface. It is thus possible under suitable conditions to use the balance to determine lines and axes of geological structure in districts built up essentially of sedimentary rocks where the solid geology is concealed by drift.[2]

Of the structures of common occurrence a steeply inclined fault is perhaps one of the most suitable for investigation by the gravitational method since, owing to the high inclination of the surface separating the lighter from the heavier material, it should

[1] 'A Gravitational Survey over the Swynnerton Dyke, Yarnfield, Staffs.', 'Summary of Progress' for 1927, pt. ii, (*Mem. Geol. Surv.*), 1928, pp. 1-14. 'A Gravitational Survey over the Buried Kelvin Valley at Drumry, near Glasgow,' *Trans. Roy. Soc. Edin.*, vol. lvi, part 1 (No. 7), 1929, pp. 141-155.

[2] 'The use of the Torsion Balance in the Investigation of Geological Structure in South-West Persia,' 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, pp. 168-196; J. H. Jones and R. Davies, 'The Measurement of the Second Derivatives of the Gravitational Potential over a Buried Anticline,' *Monthly Notices of Roy. Astron. Soc., Geophys. Suppl.*, vol. ii, no. 1, 1928, pp. 1-32.

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be readily detectable by a short traverse at right angles to the strike. The survey described in the present paper was undertaken to test the practical value of the method in detecting a fault in drift-covered country.

There are few published accounts of the results of such surveys. Barton[1] gives a short description of the results of a traverse across the Luling fault, Caldwell County, Texas, and also mentions the reported successful location of faults by the torsion balance in the Panuco district of Mexico, although no published details are available.

The fault selected for investigation is the well-known Pentland Fault, a powerful dislocation of great importance in the Edinburgh district. The course of this fault, although it is never actually exposed, can be mapped with accuracy for several miles; its trend is N.N.E.-S.S.W. At the northern end for a distance of two miles between Craigmillar and Portobello, on the Firth of Forth, its course is completely obscured by glacial and raised beach deposits, In this area the geological map, one-inch Sheet 32, Scotland, shows the lower horizons of the Calciferous Sandstone Series brought against the higher beds belonging to the Oil-Shale Group, of the same series. The site of the survey lies about one mile south of Portobello where the inferred course of the fault passes under the deposits of the 100-foot Raised Beach. The terrain is moderately flat and the superficial deposits are, as far as is known, of homogeneous character and uniform in thickness.

The geology of the district, shown in Fig. 1, is reproduced from the six-inch Geological Survey map, Edinburgh 4 S.W., published 1906, and amended in accordance with the new solid edition of the one-inch map, at present being engraved. The only exposures of rock are north of Duddingston Loch and at the positions shown by the dip arrows on the south and east of the map. The remainder of the area is covered by drift and alluvium, and the course of the fault, the outcrops and the geological boundaries are inferred from the general structure of the district. There is a considerable amount of mining evidence regarding the nature and disposition of the rocks on the east, or downthrow, side of the fault. Definite stratigraphical horizons have been recognised and the strata dip at high angles towards the east. Practically nothing is known regarding the rocks on the west, or upthrow, side of the fault. In this connection the extent and thickness of the basic volcanic rocks of Arthur's Seat[2] are of importance. At their outcrop, about 1½ miles west of the line of the fault in the area surveyed, these rocks have a thickness of about 1,000 ft. On the old edition of the one-inch Geological Survey map, Sheet 32, the eastern limit of

[1] Barton, D. C., 'The Eötvös Torsion Balance Method of Mapping Geologic Structure,' *Am. Inst. Min. Met. Eng.*, Technical Publication No. 50, 1928, p. 37.

[2] Arthur's Seat is a prominent hill lying ½ mile N.N.W. of Duddingston Loch (Fig. 1).

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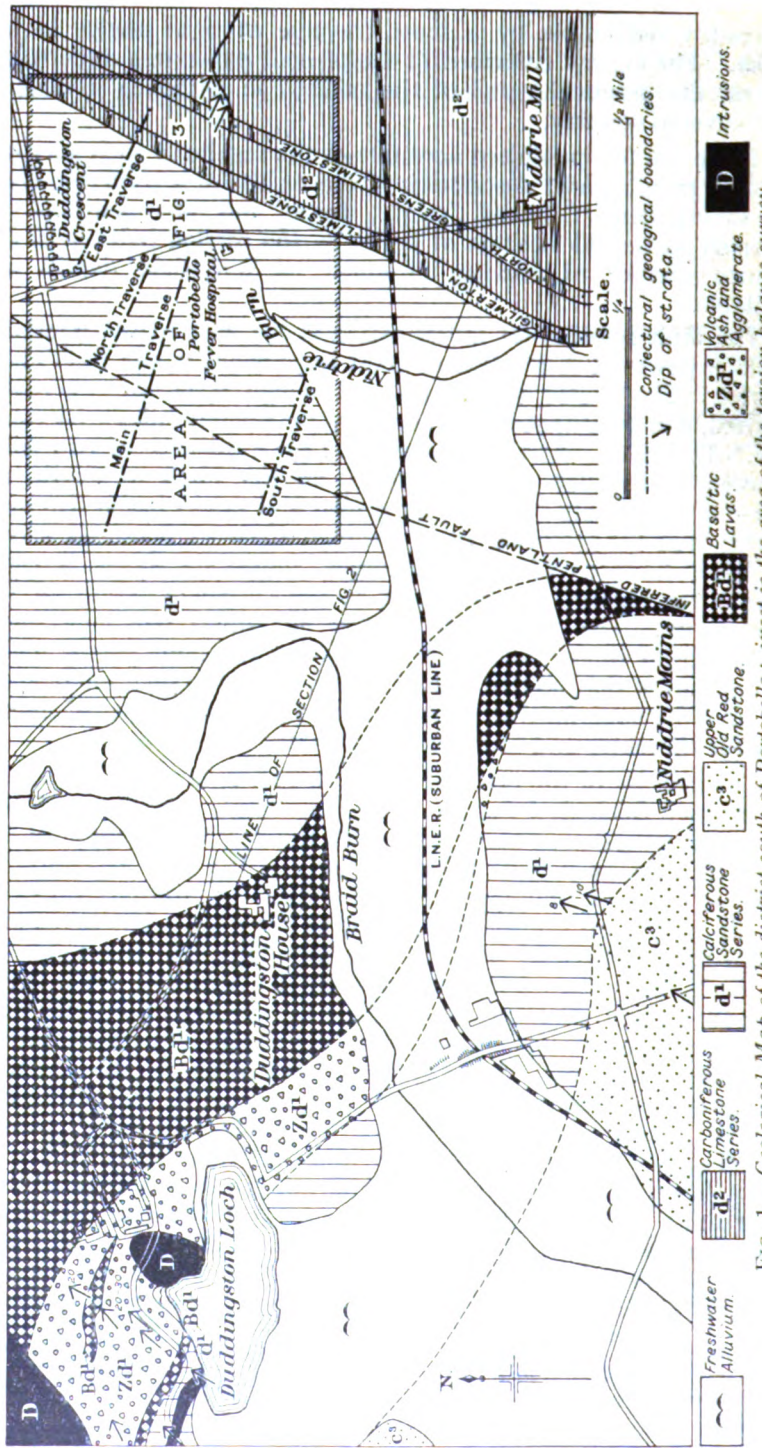

FIG. 1.—*Geological Map of the district south of Portobello ; inset is the area of the torsion balance survey.*

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their outcrop lies about ½ mile west of the fault ; on the new edition at present being engraved they are inferred to come up to the fault (Fig. 1) but to be much thinner there than on Arthur's Seat. This view is also illustrated in the section (Fig. 2) prepared by the Geological Survey for the construction of a geological model

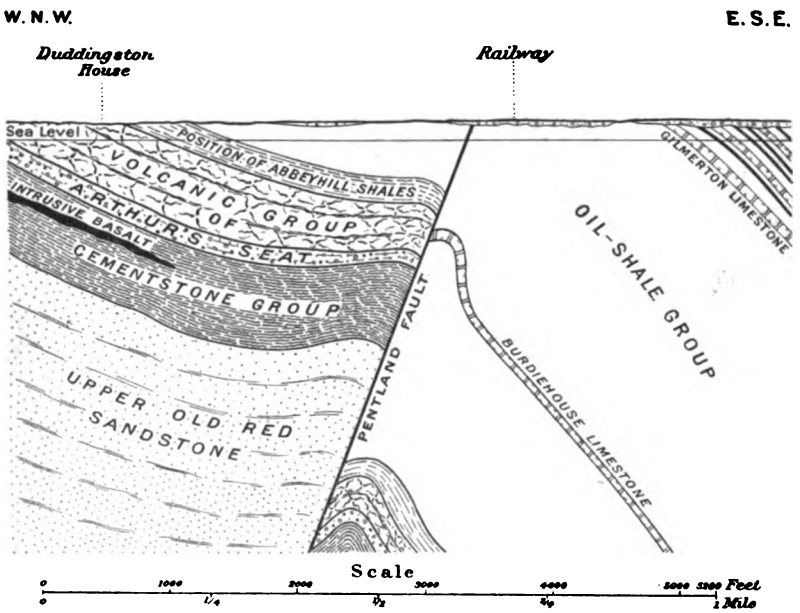

FIG. 2.—*Geological Section along the line shown on Fig.* 1.

of the district. The section shows the lavas, 500 ft. thick, reaching the fault at a depth of 600 ft. The complete absence of outcrops or boring information renders any interpretation conjectural.

The Pentland Fault is generally considered to be a steeply inclined reversed fault or overthrust, and, in the event of a thick series of heavy basic lavas being brought against much lighter sedimentary rocks along such a steeply inclined interface, large gravitational effects are to be anticipated. If, on the other hand, the lavas die out at a considerable distance from the dislocation, which in that case would bring sediments of slightly different age into juxtaposition down to a depth of at least 2,000 ft., then there might still be sufficient difference in specific gravity between the younger rocks on the east and the older rocks on the west to yield the gravitational effects necessary to map the plane of discordance.

Operations were begun in October, 1928, and continued till the end of December. In all, 53 stations were determined by visual observation at night.

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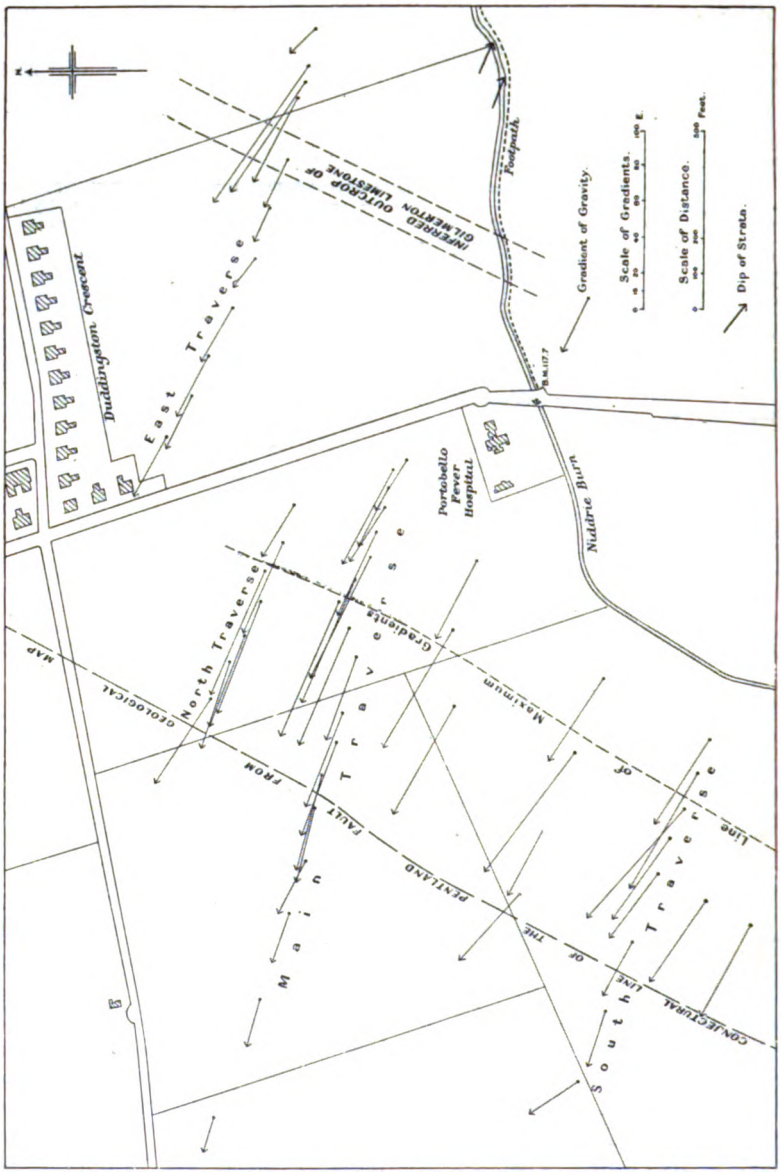

FIG. 3.—*Chart of residual gradients.*

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RESULTS OF THE TORSION BALANCE SURVEY

Four traverses were made with the balance across the inferred strike of the structure and additional observations were made at critical positions in the area between the main and south traverses. The results are plotted on the map, Fig. 3, which shows the magnitude and direction of the residual gradients of gravity determined at 53 stations. The outstanding features are the general parallelism of direction of the gradients on each traverse and the complete absence of reversal, all the gradients being directed towards the west-north-west. The largest gradients are found along a line nearly parallel to, and 180 yards east of, the conjectural line of the fault. East and west of this line the gradients fall off rapidly; the variation in their value along each line of traverse is shown graphically and more clearly in Figs. 4, 6, 7 and 8.

The constant west-north-westerly trend and the type of variation of the gradients indicate that a heavy subterranean mass of rock lies to the west and that the surface separating it from the lighter rocks to the east is very steeply inclined to the horizontal, that is, the structure is probably a fault. From theory, the strike of such a structure ought to follow very closely the line of maximum gradients, whose course is shown on the map, and the average direction of the gradients along each traverse should therefore be at right angles to that line. The following table shows how closely the experimental results of the survey confirm this expectation.

	South Traverse	Main Traverse	North Traverse
Direction at right angles to the average gradient direction	34½° E. of N.	24° E. of N.	22½° E. of N.
Direction of line of maximum gradient = strike of fault	30° E. of N.	25° E. of N.	22° E. of N.

Qualitatively, therefore, the gravitational measurements clearly indicate the presence of a fault very close to the position previously inferred from the general geology.

There follows a detailed examination of the results on each traverse and an attempt is made to supply a quantitative interpretation in accordance with what is known of the geology of the district. The stations on the east traverse lie wholly east of the fault but, along the strike, overlap the eastern stations of the main traverse. They were determined in order to carry the observations into ground where the nature and dip of the strata are definitely known. The gradients are directed a little more to the north than those in the traverses to the west and are practically at right angles to the known strike of the rocks; a detailed interpretation is given below.

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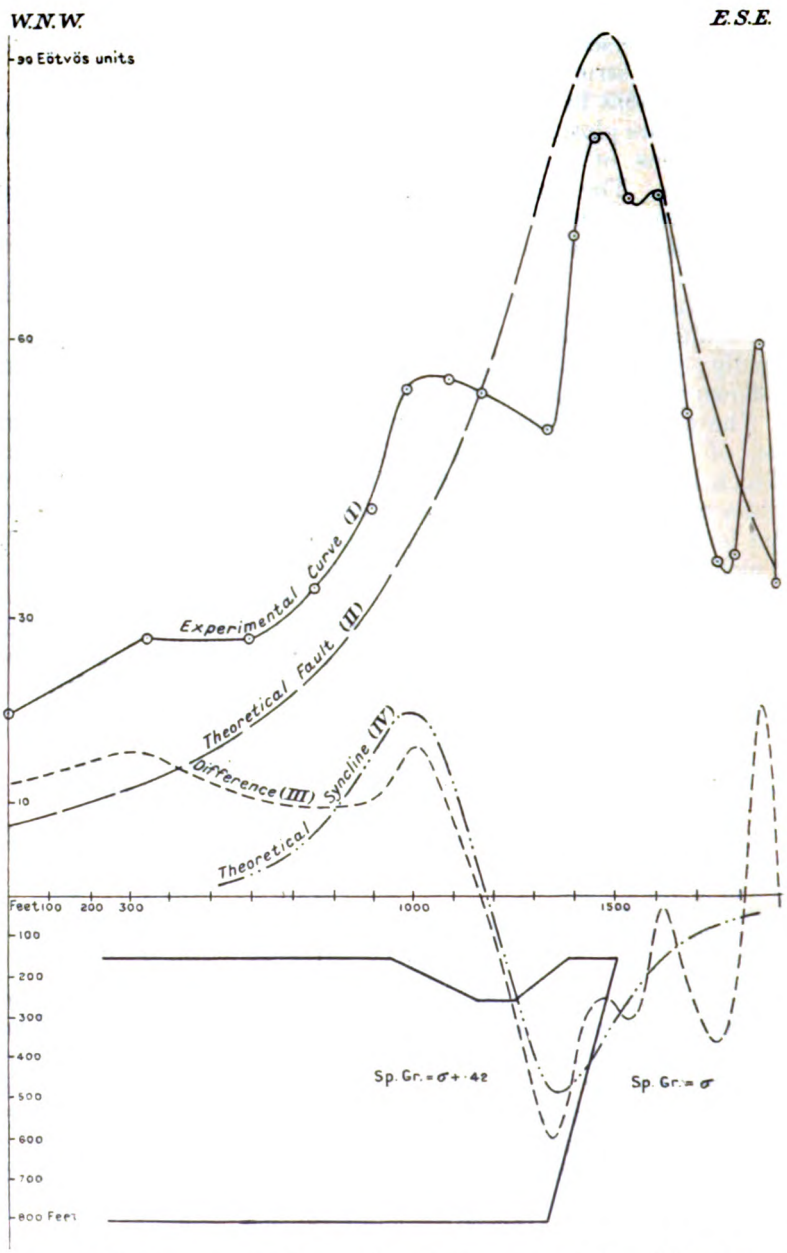

FIG. 4.—*Main Traverse. (I) Curve of gradient components parallel to traverse; (II) Theoretical curve of gradients due to the fault shown in lower part of figure; (III) Curve of difference between (I) and (II); (IV) Theoretical curve of gradients due to syncline as shown.*

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The Main Traverse.—Fig. 4 shows in graphical form the variation in value of the gradients along this line. In this and subsequent figures the values plotted are the components of the gradients along the average gradient direction of each traverse, positive ordinates representing gradients directed W.N.W., and negative ordinates those in the reverse direction. The experimental curve (I), Fig. 4, clearly arises from a fault-like structure but marked irregularities indicate that, in addition to the fault, minor structures are present. The theoretical curve (II) drawn for the fault-block with the position, thickness and specific gravity difference indicated in the lower part of the figure bisects roughly the irregularities in the experimental curve and may be taken as a first approximation to the main structure. The difference between the two curves is shown graphically in curve (III). It may be largely accounted for if we assume that the rocks immediately to the west of the fault-plane are folded into an asymmetrical syncline of the dimensions indicated. Curve (IV) shows the values of the gradients calculated for this syncline.

The final difference between the experimental gradients and those due to the fault combined with the syncline are plotted on Fig. 5. Quantitative interpretation of these differences is

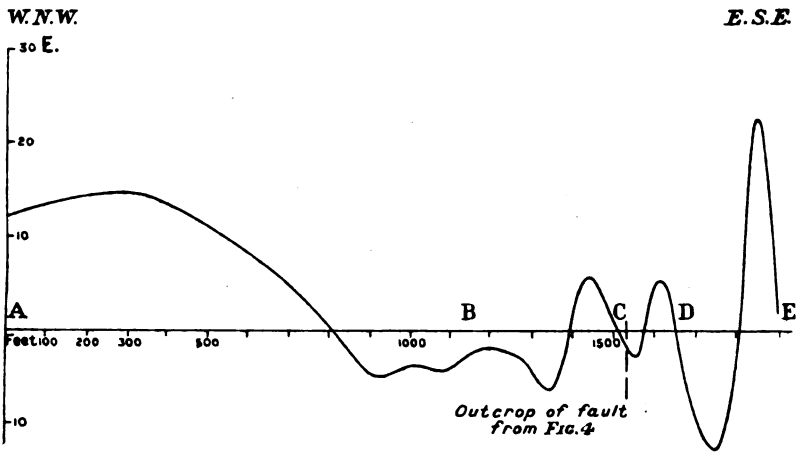

FIG. 5.—*Difference between experimental gradient components and theoretical gradients due to the combined fault and syncline shown in* FIG. 4.

impracticable but they suggest qualitative deductions that are geologically probable. The residual gradients from B to A point to a flattening of the dip of the western flank of the syncline and to a continued westward rise of the dense rock. The small rapidly changing residue between B, C and D is probably to be correlated with intense folding and with irregularities in the rock-drift interface in the immediate neighbourhood of the fault. The part of the curve between D and E may bear two interpretations. First, it may be due to a local rock-knob rising through the drift; in

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this event the traverse has so cut across it that the direction of the gradients is not altered (see Fig. 3). Second, it may be due to the existence of a narrow, very steeply inclined heavy stratum, parallel to the fault. If such a stratum were continuous along the strike we should expect it to cause similar variation in the values of the gradients at the western stations of the east traverse (see Fig. 3). Although there is some marked irregularity at these stations (see Fig. 8) sufficient observations have not been made to show whether the large and rapid variations under discussion are there reproduced in detail; comparison of the magnitude of the gradients and the distance between the stations shows that their occurrence is possible. It may be noted that if the variations between the positions D and E (Fig. 5) are due to a heavy stratum then, from the asymmetry of the curve, it dips towards the west—that is, like the fault itself, the strata immediately east of the fault-plane are reversed.

So far no reference has been made to the magnitude of the throw of the fault, in other words, to the position of the heavy block on the east or downthrow side of the fracture. All the evidence available from mining and from exposures near the fault shows that on the east the strata are very steep. Hence the heavy block on the west must occur on the east as a very acute, almost vertical wedge lying against the fault-plane (cf. Fig. 2.) If the top of this wedge lies at 1,000 feet from the surface, that is, the throw of the fault is 850 feet, its gradient effect does not exceed about 6E. within 500 feet on either side of the fault. Thus within the critical area of the survey we may consider the interpretation advanced above to be valid on the assumption that the throw of the fault is at least 850 feet; how much more it may be we cannot say.

The North Traverse.—The results obtained here are of the same type as in the main traverse. The value of the maximum gradient is lower, however, and this may point to the lowering of the heavy block by pitch towards the north-north-west. Such a pitch is known from geological evidence to be the case, but in view of the number of complications in the vicinity of the fault we do not stress this decrease in maximum gradient as a direct gravitational proof of pitch.

It is to be noted that the distance between the maximum and minimum turning values on the curve (Fig. 6) is 280 ft.; the corresponding points on the curve for the main traverse (Fig. 4) are 150 feet apart. We may conclude, therefore, that the east flank of the syncline west of the fault is 130 feet farther west in the north than in the main traverse. This indicates that the syncline probably strikes more directly north and south than does the fault.

The South Traverse.—The experimental gradients are shown by the curve (A), Fig. 7. This curve is steeper on the west than on the east and to that extent indicates that the gradients are due to a

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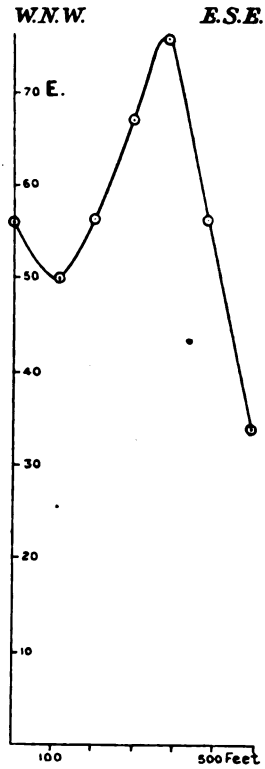

FIG. 6.—*Gradient components along north traverse.*

normal fault hading towards the *east.* A steep normal fault structure, with very large throw, can easily be found, which will yield a gradient curve almost coincident with the critical part of the experimental curve ; the position and dimensions of the block on the west would be, in that case, depth from surface 60 feet, thickness of block about 720 feet, with a specific gravity ·22 greater than the lighter rocks on the east. If, however, we attempt to interpret the results along the main traverse by a similar structure large gradients remain which cannot be explained by assuming any subsidiary structure which is geologically probable.

On the other hand, if we assume the fault to be reversed and the heavy block on the west to lie at 120 feet from the surface, to have a thickness of approximately 680 feet, and a specific gravity difference of ·42, we obtain the theoretical curve (B). Curve (C) shows the difference between curves (A) and (B). This difference can be readily explained, as shown in Fig. 7, by assuming a steep westerly dip of the heavy strata away from the fault—that is, a minor structure of monoclinal type. Curve (D) shows the calculated values for this structure. It is practically coincident

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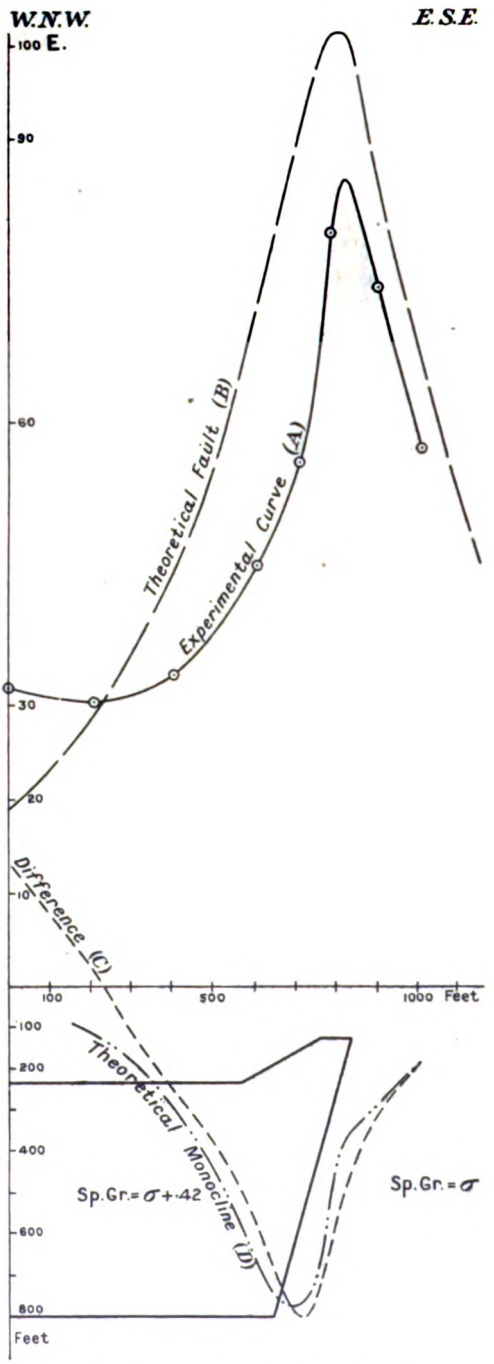

FIG. 7.—*South Traverse. (A) Curve of gradient components parallel to traverse; (B) Theoretical curve of gradients due to the fault shown in lower part of figure; (C) Curve of difference between (A) and (B); (D) Theoretical curve of gradients due to the monocline shown in lower part of figure.*

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with the difference curve (C) over the critical area and, as in the main traverse, arises from a structure which is geologically probable. There still remains a considerable difference at the western end of the traverse, accountable as before (p. 17) by a gradual rise of the heavy rock towards the west.

The East Traverse.—Owing to the existence of the deep channel of the Niddrie Burn the main traverse could not be extended farther east than as shown on Figs. 1 and 3. North-east of the main traverse a line was therefore selected which would afford a series of practically collinear stations, overlapping on the west the eastern stations of the main traverse and enabling observations to be extended uninterruptedly eastwards into an area where the structure can be fairly definitely inferred from quarrying and mining evidence. As shown on Fig. 3, the line crosses the inferred outcrop of the Gilmerton Limestone, a band 60 feet thick in places and in this area taken as the base of the coal-bearing series. As the strata are highly inclined, and compact limestone has a comparatively high specific gravity, it was hoped to confirm the position of the Gilmerton Limestone from the balance results.

The traverse yielded a series of parallel gradients (Fig. 3) which are directed a little more north of west than the gradients of the north and main traverses. This is probably due to the strike of the strata being a little more east of north than the strike of the fault. Fig. 8 shows the curve of gradient components along this traverse. Numerically we find that the western stations yield approximately the same values as the eastern stations of the main traverse but without the rapid variation there noted. We have already pointed out, however, that the occurrence of such rapid variation of gradient must not be excluded as impossible since the stations are fairly wide apart. About the middle of the east traverse the gradients decrease in magnitude rapidly to a minimum value while retaining their direction. If this decrease is due to the existence of a bed of heavy limestone, 60 feet thick and dipping towards the east at 45°, the approximate position of the centre of the bed is as shown in Fig. 8. This position is 135 feet west of the inferred outcrop of the Gilmerton Limestone. At the east end of the traverse the gradient curve rises very steeply to a peak and falls again very quickly. The type of curve, the small distance over which the gradients vary so rapidly and the deflection of the gradients as shown in Fig. 3, suggest the presence of a subdrift feature at shallow depth in this locality. On the assumption that the general westerly gradient due to the fault combined with easterly dip of the strata, is here about 20 E., the feature may be interpreted as a rock cliff of 40 ft. buried under 20 ft. of drift whose specific gravity is ·6 lower than that of the rock. The calculated thickness of drift west of the position of maximum gradient is therefore about 20 ft., while on the east it is 60 feet. Very little is actually known about the

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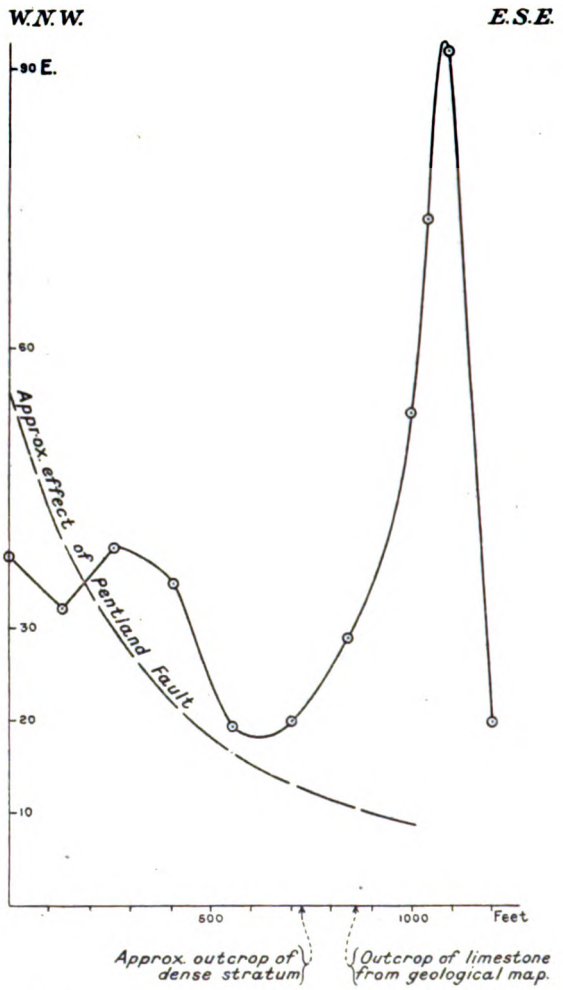

FIG. 8.—*Gradient components along east traverse.*

depth of drift in this area, but 150 yards to the south, rock is exposed in the Niddrie Burn (Fig. 3) which is here only 20 feet below the level of the stations in question.

Curvature values.—The determination of residual curvature values due to sub-surface structure demands topographic corrections much more detailed and extensive than in the case of gradients. In the present instance a considerable part of the area was contoured at 5-foot intervals, and topographic corrections were calculated up to a distance of 2,000 feet from most of the station points. From 2,000 to 10,000 feet corrections were similarly applied by the net method, using the 25-foot, 50-foot, and 100-foot contour intervals on the six-inch maps. The residual curvature vectors

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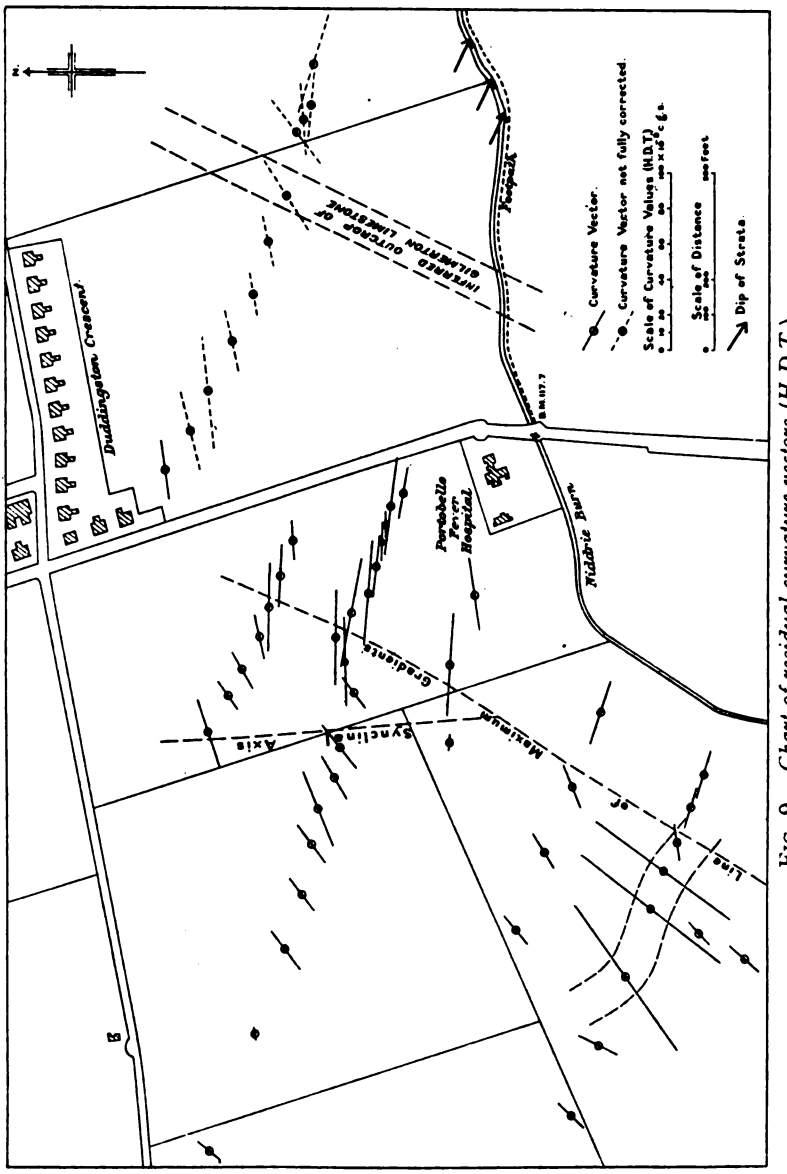

FIG. 9.—*Chart of residual curvature vectors (H.D.T.).*

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due to the structure, after application of the corrections so obtained, are plotted on Fig. 9. From theory they ought to lie parallel to the fault on the upthrow side and at right angles to it on the downthrow side[1]; this is well brought out on the chart, Fig. 9, which also shows that the change in direction takes place approximately along the line of maximum gradient. In the neighbourhood of the synclinal axis deduced from the gradients (p. 17) the curvatures show a distinct departure from the N.N.E. direction and tend to lie across this axis; this again is to be expected from theory.[2]

The three anomalously large curvature values shown in the south traverse require explanation. They lie parallel to the fault but their values are more than twice as great as those calculated for the structure inferred from the gradients. It is to be noted that these large values fall away very suddenly at neighbouring stations, whilst the most westerly of the three shows a distinct change in direction; further, the gradients at the stations in question are not anomalous (see Fig. 7). The facts suggest that the structure causing the anomalous curvature vectors is a shallow one. A drift-filled channel, whose course is shown in the diagram by dotted lines, 120 feet wide, 40 feet deep, and buried under 20 feet of drift, would produce curvature values of about 60 E. at points above its deepest part where the gradient is zero. At points nearly above the top of the channel banks the gradients would reach their maximum value of 13–14 E. and beyond the channel both gradients and curvature values would be small. These effects when combined with the curvatures and gradients calculated for the structure already deduced for this traverse (Fig. 7) are of the order of the values measured in the field. It is of interest to note that a buried channel running E.–W. has been proved about ½ mile to the south.[3]

CORRELATION OF THE GRAVITATIONAL RESULTS WITH THE GEOLOGY OF THE DISTRICT

The interpretation of the gravitational results given above is based on the assumption that the heavy block on the west has a specific gravity higher by ·42 than the strata on the east or downthrow side. These strata are known to belong to the Calciferous Sandstone Series consisting of sandstones and shales with an average specific gravity of 2·4 determined from a series of specimens. The heavy block on the west therefore has a specific gravity of 2·82. The only known rocks west of the fault with such a high specific gravity are the volcanic group of Arthur's Seat, the mean value for which, as estimated by James,[4] is 2·75. The nearest visible outcrop of these rocks is about 1½ miles west of the fault,

[1] 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, p. 192.

[2] *Loc. cit.*, p. 191.

[3] Milne, D., 'The Midlothian and East Lothian Coalfields,' *Trans. Roy. Soc. Edin.*, vol. xiv, pt. i, 1839, pp. 313-4.

[4] 'Observations and Calculations of the Principal Triangulation of Great Britain,' 1858, p. 609.

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and the extent to which they stretch eastwards from that point was hitherto unknown (p. 13). On the geological model of the Edinburgh District in the Royal Scottish Museum they are shown as reaching the fault at a depth of 600 feet and retaining a thickness of 400 to 500 feet. The gravitational results have confirmed this eastern extension of the volcanic horizon up to the fault, and indicate that it lies at 150 to 250 feet from the surface and has a thickness of approximately 600 feet (p. 16). It must be emphasized, however, that these quantitative deductions are subject to qualification. They are based on the assumption that the gradient effects at the fault are due wholly to comparatively shallow structures, and this assumption probably does not hold. For example, at a depth of about 2,000 feet below the Arthur's Seat Group there occur the andesites, trachytes and rhyolites of Lower Old Red Sandstone age. At the fault these must be brought into juxtaposition with younger sediments of lower specific gravity. Such a deep-seated structure will give rise to a westerly gradient which will remain tolerably constant over the relatively small area surveyed; but as we know neither the throw of the fault nor the thickness of strata covering the Old Red Sandstone lavas the value of the gradient is unknown. Allowance for it would not affect the deductions already made regarding the types of structure but would alter the numerical estimates. Thus if we assume over the main traverse a constant W.N.W. gradient of 15 E. due to the deep-seated block, then the calculated dimensions and position of the shallower block are altered to thickness 400 feet, minimum depth from surface 200 feet, specific gravity difference about ·42; on these assumptions the minor structures already described would still be present but at correspondingly greater depth.

If some definite geological information were available, for instance, if the depth or the thickness of the Arthur's Seat lavas were known, more accurate quantitative deductions could be made from the balance results, and it would be possible to estimate an upper limit for the throw of the fault. Such evidence can only be obtained by boring or possibly by the application of alternative geophysical methods, for example the seismic method. The problem, in fact, illustrates the well-recognised principle that geophysical methods are complementary to one another and yield the most fruitful conclusions when they are jointly used in areas where there is a substantial basis of geological evidence to control the interpretation of the results.

SUMMARY

The structural map, Fig. 10, is based on the results of the gravitational survey which are summarized below.

(1) The variation in the gradients determined along a series of traverses clearly indicates the existence of a fault accompanied by minor folding.

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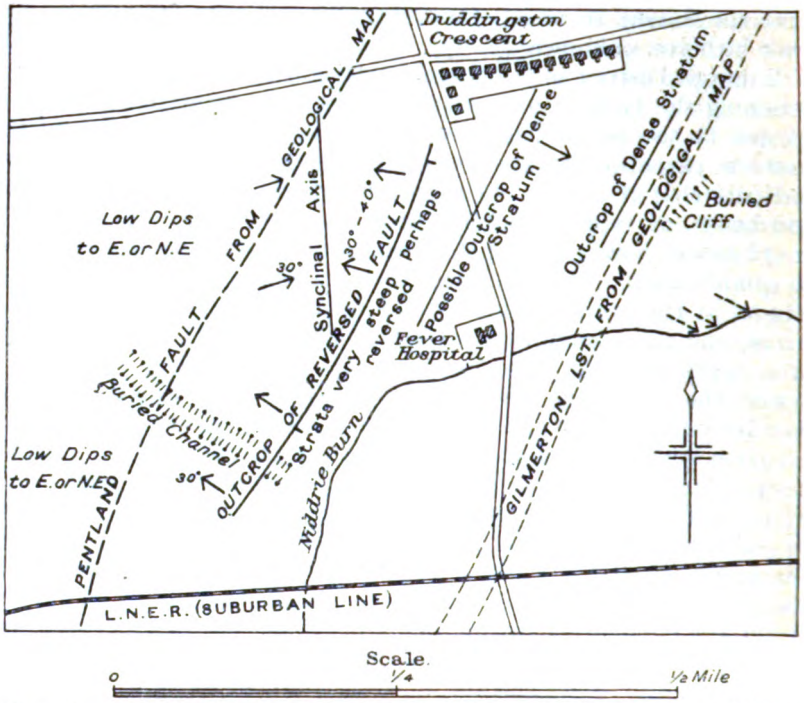

FIG. 10.—*Geological structure deduced from the gravitational survey. Lines and dips taken from the Geological Map are shown broken.*

(2) The maximum gradients on each traverse have a high value and lie on a line which is parallel to the line of the Pentland Fault as plotted on the six-inch Geological Survey map, and 180 yards east of it.

(3) The buried outcrop of the fault is close to the line of maximum gradient and its strike is at right angles, within 3–4 degrees, to the average direction of the gradients on each traverse.

(4) The fault is reversed and hades steeply towards the west or upthrow side; it strikes N.N.E.–S.S.W.

(5) The heavy horizon west of the fault is the Arthur's Seat lavas with a deduced specific gravity of 2·82. Their thickness estimated from the values of the gradients is 500–600 feet, and their depth below the surface at the fault is 150 feet; this depth is increased to fully 250 feet by sharp synclinal folding west of the fault. Reasons for possible qualification of these figures are given (p. 25).

(6) The strike of the minor folding west of the fault is deduced as almost due north and south.

(7) The strata immediately east of the fault are very steep and possibly reversed.

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(8) The strike of the sedimentary rocks deduced from the gradients along the east traverse is practically the same as the strike observed in the nearest exposures.

(9) The outcrop of a dense stratum, probably the Gilmerton Limestone, was located at 130–140 feet west of the inferred position of this limestone. The gravitational results in this area are so complicated that we doubt if this location would have been made unless the geology had been fairly accurately known.

(10) The absence of pronounced local anomalies in the gradients indicates that the surface between rock and drift is regular, as might be expected since it forms part of a raised beach. Abrupt local changes in the thickness of the drift are indicated at two places; in the one case the presence of a buried channel, in the other, a buried cliff, is suggested. The average depth of drift in the area surveyed appears to be about 20 feet.

(11) Quantitative deductions were not made from the residual curvature values, but in several respects these afforded a valuable qualitative check on the deductions made from the gradients. The existence of the shallow structure on the south traverse, which may be a buried channel, was shown by the curvatures and not by the gradients.

In conclusion we desire to acknowledge the kindness of Mr. Simpson of Duddingston Mains, and Mr. Grey of Niddrie Mains, who afforded us every facility for carrying out the investigation.

APPENDIX

Topographic corrections.—Under this head were calculated surface effects between the distances 100 ft. and 2,000 ft. from the stations. The gradient effects were at most 1·5 E. but the curvature corrections varied greatly in magnitude and direction, the highest value being 24 E. The corrections were calculated by the network method explained by Shaw and Jones,[1] the nets used being such as are suitable for use with maps on the scale of 1 : 2500 or 25·344 inches to one mile. Equations for constructing the gradient net have been given in a previous paper.[2] The equations for construction of the curvature net are derived from the formulae for the effect due to a column of height z above the station point and lying between the azimuths θ_n and θ_{n+1} in the zone $\rho=\rho_m$ to ρ_{m+1}, namely

$$U_\Delta = -\tfrac{3}{2} G\sigma z \left(\frac{1}{\rho_m} - \frac{1}{\rho_{m+1}}\right) (\sin 2\theta_{n+1} - \sin 2\theta_n)$$

$$2U_{xy} = \tfrac{3}{2} G\sigma z \left(\frac{1}{\rho_m} - \frac{1}{\rho_{m+1}}\right) (\cos 2\theta_n - \cos 2\theta_{n+1})$$

In order to obtain a net in which the outer divisions were not too large we used two constants. For the five inner zones the constant chosen was

$$\left| \left(\frac{1}{\rho_m} - \frac{1}{\rho_{m+1}}\right) (\sin 2\theta_{n+1} - \sin 2\theta_n) \right| = \cdot 01$$

[1] Shaw, H., and E. Lancaster-Jones, 'The Theory and Practical Employment of the Eötvös Torsion Balance', *Mining Mag.*, vol. xxxvi, No. 6, 1927, pp. 339-340.

[2] McLintock, W. F. P., and J. Phemister, 'A Gravitational Survey over the Buried Kelvin Valley at Drumry near Glasgow,' *Trans. Roy. Soc. Edin.*, vol. lvi, part 1, 1929, p. 147.

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and for the remaining zones up to 2,000 ft. it was ·005. The radii and circles which intersect in the effect centres of the divisions of the network are then given by

$\pm\ \theta$ = 2° 52′, 8° 44′, 15°, 22° 13′, 32° 5′, 57° 55′, 67° 47′, 75°, 81° 16′, 87° 8′.

and

ρ = 105·2, 117·6, 133·3, 153·8, 181·7, 210·5, 235·3, 266·7, 307·5, 363·5, 444, 572, 800, 1333·3 feet.

An example illustrating the use of the method in calculating U_Δ and $2U_{xy}$ is given by Shaw and Jones in the paper referred to above. It must be remembered that the relative height of the surface with respect to the station point is measured in units of 100 feet.

Cartographic corrections were not made for gradients but were estimated at several stations for curvatures by the net method between the distances 2,000 ft. and 10,000 ft. (nearly 2 miles) from the station. Since the distances from the stations are now large each quadrant was divided up by eight radii instead of by five as in the nets for topographic correction. The constant value of $\left|\left(\frac{1}{\rho_m} - \frac{1}{\rho_{m+1}}\right)(\sin 2\theta_{n+1} - \sin 2\theta_n)\right|$ was chosen as ·001 so that the dots at each effect centre would be distinct on maps drawn on the scales of three inches to one mile (1 : 21,120) and six inches to one mile (1 : 10,560). The radii and circles which intersect in the effect centres of the divisions are given by

$\pm\ \theta$ = 1° 48′, 5° 24′, 9° 6′, 13°, 17° 6′, 21° 43′, 27° 10′, 34° 49′, 55° 11′, 62° 50′, 68° 17′, 72° 54′, 77°, 80° 54′, 84° 36′, 88° 12′.

and

ρ = 2,033, 2,101, 2,174, 2,252, 2,336, 2,427, 2,525, 2,631, 2,747, 2,873, 3,012, 3,333, 3,731, 3,968, 4,237, 4,545, 4,902, 5,319, 5,814, 6,410, 7,143, 8,065, 9,260 feet.

The net is used for calculating U_Δ and $2U_{xy}$ exactly as for topographic corrections but the height of the surface relative to the station point is measured in units of 1,000 feet.

Within the area surveyed the corrections varied numerically from 20 E. to 1 E., so that we cannot assume the curvature effects completely corrected even by calculation of surface effects up to a distance of two miles.

Formulae.—No new formulae were derived for gradient or curvature effects but the following simple equations may prove of use in estimating first approximations of depth and thickness of an infinite horizontal block with vertical edge :—

Let $\Delta^2 \equiv D$ = depth of bottom of the slab.

$\delta^2 \equiv d$ = " top "

l_1 = distance between position of maximum gradient and position where gradient is $\frac{3}{4}$ maximum.

l_2 = distance between position of maximum gradient and position where gradient is $\frac{1}{2}$ maximum,

then $(\Delta + \delta)^2 = l_2 + \frac{l_2^3}{l_1^2}$

and $(\Delta - \delta)^2 = \frac{l_2^3}{l_1^2} - 3l_2$

These equations may be compared with others dealing with the same problem given by Jones and Davies.[1]

These authors make use of the positions where the gradient is respectively one half and one quarter of the maximum value.

[1] Jones, J. H., and R. Davies, 'The Measurement of the Second Derivatives of the Gravitational Potential over a Buried Anticline,' *Monthly Notices of Roy. Astron. Soc., Geophys. Suppl.*, vol. ii, no. 1, 1928, pp. 25-26.

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III.—THE INVERBEG LAMPROPHYRE

By Sir John S. Flett, K.B.E., F.R.S.

On the west side of Loch Lomond about one mile south of Inverbeg Inn there is a well-known lamprophyre dyke exposed in a quarry by the roadside. This locality is 2½ miles north of Luss and 5 miles south of Tarbet. The dyke is about 16 feet thick, runs in a direction a few degrees south of west, and dips to the south at an angle of 75 degrees. Formerly this rock was extensively quarried as a roadstone for mending the local roads, but under present conditions the quarry seems to have been abandoned, though perhaps only temporarily. During a visit to the spot in 1928 I found that active work had not been carried on at least for a season or two. Consequently, fresh broken specimens, which were to be had in any number when first I visited the quarry in 1900, were now rather difficult to obtain.

The dyke is a reddish lamprophyre of a type which is not uncommon in the Southern Highlands and belongs to a group that is associated with the Newer Granites. Evidence of this affinity is provided by the occurrence of types of Newer Granite and Diorite which are strikingly like these lamprophyres. The whole series is presumably of early Devonian or late Silurian age; they are usually entirely free from metamorphism, a feature which distinguishes them from the granites and gneisses of the 'Older' group. This dyke is marked on the one-inch geological map, Sheet 38, with the index letter SM, which is supposed to have been derived from the old name mica-syenite, formerly sometimes applied to minette.

The country rocks into which the dyke is intruded are silvery-greenish schists rich in muscovite and chlorite, and sheared greenish grits which are developing into granulitic paragneisses. Two specimens (26736, 26737) taken from the rocks adjoining the quarry were sliced and examined with the microscope. In both the clastic origin of the rock is evident as they contain pebbles of quartz and felspar, which are large and obvious; they are surrounded by a matrix which has a parallel schistose structure owing to the abundance of fine scaly muscovite and green chlorite mixed with smaller quartz and felspar grains, irregular in shape but often arranged in lenticles parallel to the foliation. The minerals are, in approximate order of abundance, quartz, alkali-felspar, muscovite, chlorite and carbonates. The scanty accessories are iron ores, rutile, apatite, sphene, tourmaline and zircon. Here and there a small irregular flake of greenish-brown biotite makes its appearance. Garnet seems to be absent. Closer examination of the felspars reveals that they are practically all orthoclase and albite as every crystal showing plagioclase twinning has a lower refractive index than quartz and Canada balsam.

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The maps of this neighbourhood were revised by Mr. E. H. Cunningham Craig[1] who places this series in his Ben Ledi Group. He has given a description of their petrographical characters in his paper on Metamorphism in the Loch Lomond district. The special feature that concerns us at present is the low state of their metamorphism. These sheared grits of the districts adjoining the Highland border are recognised as coarse quartzo-felspathic sediments in which the obliteration of the clastic structures is only very incomplete and the development of new minerals has hardly progressed beyond the formation of a limited amount of white mica and clear albite.

Many of the larger pebbles of quartz are broken up into a mosaic of interlocking angular grains, though some have merely an irregular dappled extinction between crossed nicols that shows they are in a state of strain. The felspar pebbles are less frequently crushed. As a rule these larger elements of the rock have elliptical or lenticular shapes with their longer axes parallel to the schistosity.

The rock of which the dyke consists is a fairly typical lamprophyre of the vogesite group; its dominant minerals are felspar and hornblende with, in some specimens, a fair amount of biotite. The structure is of the 'panidiomorphic' type, as all the minerals, though never perfect, usually show well developed crystalline form. The state of preservation varies in different specimens but as a rule there is a good deal of decomposition. The greenish-yellow hornblende is often replaced by chlorite and epidote (?), the felspar is cloudy and filled with small micaceous scales, and the yellow biotite seldom gives its high polarization colours over the whole extent of a crystal. The exact nature of the felspar cannot always be determined but there is a considerable amount of untwinned felspar which is presumably orthoclase and a nearly equal amount of polysynthetic felspar which has a low refractive index indicating that it belongs to the oligoclase and albite series.

The special interest of this dyke, however, arises from the variety and number of its inclusions. These were strikingly evident in the debris of the quarry and might be collected in large numbers when the rock was being worked as road metal. The inclusions are seldom more than three or four inches in diameter and most of them are the size of a walnut or less. They may be divided into two groups,[2] the 'homoeogenetic' which consist of the same minerals as the igneous rock itself, and the 'enallogenetic' which consist of foreign or derived materials caught up by the igneous rock.

Belonging to the former class are certain reddish lumps that consist of felspar and hornblende in crystals considerably larger than those that form the groundmass of the rock. A section of

[1] 'Metamorphism in the Loch Lomond District,' *Quart. Journ. Geol. Soc.*, vol. lx, 1904, p. 10.

[2] Lacroix, A., 'Enclaves des Roches Volcaniques,' 1893.

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one of these masses shows that the main components are alkali-felspar, both simply twinned and polysynthetic, greenish-brown idiomorphic hornblende, a little yellow biotite and a few large crystals of albite. This, in fact, might be described as a coarsely crystalline vogesite and little difficulty would be found in accepting it as of purely igneous origin.

There is a good deal of evidence, however, to show that these crystalline masses of felspar and hornblende are connected with the absorption of foreign inclusions. Some of them are rich in biotite and towards their centres have fragments of undigested sedimentary schist. They seem to have arisen from the felspathization of a schist fragment, permeated by the magma of the rock (26732). One very instructive section (10194) shows a group of large felspar crystals containing two rounded corroded pink garnets. These garnets have a narrow black border, showing that they were undergoing absorption. They are apparently the last relics of a piece of garnetiferous schist which has been assimilated by the igneous rock. The same process though incomplete is shown by many of the recognizable schist inclusions, which have borders of varying breadth consisting of coarsely crystalline felspar. Only the smallest xenoliths have been completely digested and replaced by minerals similar to those of the lamprophyre itself.

Of the true xenoliths or foreign inclusions in the dyke there is a considerable variety; in fact, it would almost be true to say that no two are strictly similar and each presents characters indicating a different origin. Only twelve have been sliced for the purposes of this investigation and at present it is difficult to obtain more, but should the quarry be worked again some very interesting results might be expected.

Probably the commonest inclusions are rounded lumps of clear white quartz which no doubt have come from the quartz veins in the adjacent rocks of the Ben Ledi group. They are usually much rounded by solution. The other inclusions are nearly all greenish schists, dark in colour and fine-grained. Except that they show occasionally clear grey quartz and pink garnets as large as a barleycorn, there is nothing about them that is characteristic to naked eye inspection. Under the microscope, however, they show many features of interest.

Their original characters can in most cases be inferred only indirectly; they are usually much weathered and full of chlorite replacing biotite, hornblende, etc. Besides, they have often suffered contact alteration accompanied by a considerable amount of magmatic assimilation.

Fragments having large rounded quartz grains enclosed in a schistose matrix of quartz, felspar and chlorite (10192, 26734) are probably derived from the Ben Ledi schists and grits of the immediate neighbourhood.

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Another fragment (12913) has the characters of a hornblende-schist. It consists of dark green hornblende differing in colour and pleochroism from the hornblende of the vogesite, and turbid felspar, which is mostly alkali-felspar. A foliated structure is pretty obvious in the microscopic section, especially in the arrangement of the clustered, ill-shaped hornblende prisms. This hornblende-schist is an igneous rock; another hornblende-schist has a pale green hornblende and looks to be a sedimentary schist. It possibly represents the 'green beds' that have been described by Mr. Cunningham Craig.

One curious inclusion has a spotted character owing to the presence of many rounded felspar grains. These are surrounded by brown biotite plates in a matrix of felspar. This rock is evidently intensely contact altered. In some respects it has a resemblance to the albite-gneisses but the felspar which is for the most part alkali-felspar has negative optical sign while albite is positive.

The most interesting inclusions, however, are those which contain a pink garnet that seems to be almandine (alumina-iron garnet). In many of these the garnet is visible to the unaided eye. These rocks are all highly schistose, even though many of them are intensely contact altered; they are in no respect hornfelses. They are often much decomposed and contain biotite and chlorite with abundant felspar. The chlorite is clearly secondary but the biotite seems often due to contact alteration. Muscovite is not present; presumably it has been altered to felspar. In addition to garnet they mostly contain brown staurolite, which seems to be a primary mineral of the schist. On the other hand the occasional presence of sillimanite, cordierite and corundum is to be ascribed to contact alteration. Neither kyanite nor andalusite has been observed in any of these rocks but both might reasonably be expected to be present if a larger collection of specimens had been made.

The garnet crystals are in nearly all cases intensely corroded. Wherever they have been touched by the magma they are surrounded by a dark zone which consists of chlorite with magnetite. In places the dark magnetite grains have transparent greenish borders so that they belong partly to spinel. Often the smaller garnets are entirely replaced by pseudomorphs of this nature, of which the origin is indicated only by the rounded shape. In other cases a core of garnet remains, sometimes of very irregular outline. Some crystals look as if they had been melted, and dendritic crystallitic growths appear in them; around others there is a narrow zone that looks like brown glass. The melting of almandine enclosed in volcanic rocks is well known and has been described and figured by Brauns.[1] It seems, however, a little difficult to believe that glass

[1] Brauns, R., 'Die chemische Zusammensetzung granatführender kristalliner Schiefer, Cordieritgesteine und Sanidinite aus dem Laacher Seegebiet,' *Neues. Jahrbuch f. Min.*, B.-B. xxxiv, 1912, p. 85. Pl. v.

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would appear in a well crystallized rock like this lamprophyre, but Mr. H. G. Smith has recently shown me quartz inclusions in a minette from near Sedbergh that are undoubtedly surrounded and penetrated by films of brownish glass.

It is unfortunate that the decomposition of these inclusions is so general that it is impossible to be certain as to the original mineral or minerals represented by the chlorite enveloping the garnet residues. Comparative studies have shown that inclusions of almandine in igneous rocks may yield biotite, cordierite, hypersthene, augite, and even in some cases corundum. Probably much depends on the nature of the magma that attacked them.

The staurolite shows the same phenomena as the garnet except that it does not yield compact masses of chlorite. The characteristic outlines of the crystals are mostly preserved and in the interior there is generally an unchanged residue of irregular shape showing the colour, pleochroism and other optical properties of typical staurolite. Around this there is a dark zone consisting of magnetite and green spinel in densely crowded, perfectly formed little octahedral crystals.[1] Brauns has reported the production of corundum from staurolite[2] but this has not been seen in the Inverbeg rock though corundum occurs in some of the intrusions.

Around the corroded staurolites there is generally a clear zone, so that they form the centres of rounded white spots. In polarised light these spots prove to be clusters of rather large crystals of alkali (?) felspar. In fact the staurolites are giving place to aggregates of felspar and spinel, a process which indicates interfusion with the magma. Around the smaller garnets a similar zone can also be traced, though by no means so conspicuous. Brauns has described ejected fragments of garnet and staurolite schist in the Eifel tuffs that have been converted into sanidinites through the influence of hot gases from the magma. Their garnets and staurolites show exactly the same changes as we have described above. It should be noted that in a few instances small garnets and staurolites are seen that have not suffered any corrosion or alteration, but such crystals are entirely surrounded by the schist and seem to have escaped attack by the magma owing to this protection.

The garnetiferous and staurolite-bearing inclusions all show intense contact alteration. Some are completely recrystallized into masses that consist mainly of felspar and biotite; others still have their original schistose character fairly well preserved. Of the special minerals developed in them we may mention (1) sillimanite, in very typical needles and brushes, in one slide only (12912); (2) corundum, a few small grains of bluish colour in the

[1] Brauns, R., 'Die kristallinen Schiefer des Laacher Seegebietes und ihre Umbildung zu Sanidinit,' Stuttgart, 1911, Pl. 5, fig. 3; and Smith, H. G., 'The Lurgecombe Mill Lamprophyre and its Inclusions,' *Quart. Journ. Geol. Soc.*, vol. lxxii, 1916, p. 81; Koch, Max, 'Die Kersantite des Unterharzes,' *Jahrb. d. K. Preuss. Geol. Landesanst.* 1886, p. 44.

[2] Brauns, R., *Ibid.*, Pl. 5, fig. 4.

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same slide; (3) cordierite, rather doubtful in most cases and probably decomposed but almost certainly present in one slide.

From the above evidence it seems a fair inference that the lamprophyre of Inverbeg contains inclusions of several types of foliated metamorphic rocks. It is not possible to refer these specimens exactly and without ambiguity to their original sources. The intense contact alteration which they have undergone has changed their characters to a considerable extent. Yet it seems quite clear that many of them are much more metamorphic than the schists and sheared grits of the Ben Ledi series which are the country rocks at Inverbeg. As these inclusions must have been carried up from below, probably from depths of several thousand feet, by the rise of the magma, we are at liberty to conclude that garnetiferous and staurolitic schists underlie the Ben Ledi series near the south end of Loch Lomond.

As we pass northward from Inverbeg along the shores of Loch Lomond there is a steady increase of metamorphism. Albite-gneisses, hornblende-schists, and other highly foliated rocks are prevailing types. Then come the 'Green Beds' (sedimentary gneisses containing hornblende), the Loch Tay Limestone and the Garnetiferous Mica Schist.

From the Inverbeg lamprophyre I have obtained only one piece of limestone. It is dark grey, coarsely crystalline, evidently re-crystallized and contains small rhombic dodecahedra of yellow garnet. It is not possible to assert that it comes from the Loch Tay Limestone, though there seems no reason why that might not have been its source.

The only rock in the Loch Lomond basin that contains large almandine crystals is the Garnetiferous Mica Schist which is the rock that accompanies the Loch Tay Limestone on its northern side. That rock, however, has never been reported to contain staurolite. In other respects it is not unlike the garnetiferous inclusions in the Inverbeg lamprophyre.

When we search for the origin of the staurolite we are almost completely at a loss. It is not probable that this mineral was developed by the thermal action of the dyke, at great depths and under great pressure. It seems to be an original mineral of the schist. The same conclusion has been reached by Brauns with respect to the staurolite-schists of the Eifel. Now staurolite in the Southern Highlands of Scotland has a distribution that suggests that it is a contact mineral of the Older Igneous Intrusions. It was not found in Cowal by Clough and is not reported west of the Garry in Perthshire. In Aberdeenshire and Banffshire, however, it is very widespread and has been reported by Heddle, Hinxman, Barrow, Read and other geologists from many localities. It is very frequently, though not always, associated with masses of igneous gneiss or foliated granite. Becke[1] has shown that it may

[1] Becke, F., Tschermak's Min. Pet. Mitteil, vol. 34, 1917, p. 67.

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be developed by pressure at the expense of original cordierite. It is possible accordingly that deeply situated below Inverbeg there may be masses of Older Granite. This is not unreasonable but there is no other evidence of it. There is no Older Granite in Argyllshire or Stirlingshire; the nearest rocks of this type occur near Pitlochry, sixty miles to the north-east of Inverbeg.

These facts bring us to the consideration of one of the most obscure and debatable problems of Scottish Highland geology. It has generally been held by those who have mapped and described this ground that there is an ascending sequence from the Highland border northwards. From this statement we must exclude the narrow zone of border rocks which contain fossils of Cambrian age and are in many places faulted against the Highland schists that lie to the north of them, though the presence of a fault separating these two has not always been conceded. The Ben Ledi Series, however, has usually been regarded as underlying the Loch Tay Limestone and the Garnetiferous Mica Schist. Reference may be made to Cunningham Craig's descriptions of Loch Lomond-side, and to the memoir on Blair Atholl and Pitlochry (Sheet 55) and Mr. Barrow also has repeatedly stated that the sequence ascends from near the Highland border in a north-westward direction. I have not been able to find that Clough committed himself to this opinion in the Cowal memoir and recently Mr. Tilley had directed attention to some anomalies in the situation.[1] If it is true it is inconvenient for those who maintain that degree of metamorphism is dependent to a large extent on depth of situation, for the Loch Tay Series is far more highly metamorphic than the Ben Ledi Series, a fact universally admitted. I am well aware that there are difficulties to be faced, no matter which sequence we adopt. If the inclusions in the Inverbeg lamprophyre dyke are trustworthy indications of the nature of the underlying rocks it is difficult to avoid the conclusion that the Ben Ledi grits and schists rest upon a more metamorphic series that has the characters of the rocks that outcrop to the north of Inverbeg, and consequently that the sequence in this part of the Southern Highlands is an ascending one from north to south.

[1] Tilley, C. E., 'A Preliminary Survey of Metamorphic Zones in the Southern Highlands of Scotland,' *Quart. Journ. Geol. Soc.*, vol. lxxxi, 1925, p. 107.

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IV.—THE ZONAL SUCCESSION IN THE COAL MEASURES AROUND MANCHESTER

By W. B. Wright, Sc.D.

Plates I, II, III

INTRODUCTION

The Middle Coal Measures of Lancashire have a thickness of 5,500 feet from the Arley Mine to the base of the Ardwick Series. Of these the upper 2,000 feet are very little known, but as *Anthracomya phillipsi* occurs at their base it is to be presumed that they belong to this zone. In Lancashire the highest known Carbonicolas, probably impoverished representatives of the long range form *C. aquilina*, occur 200 feet below the Dukinfield Marine Band, but a fauna of Anthracomyas quite distinct from the *phillipsi* group is found below the Worsley Four Foot Mine, that is to say in a position presumably stratigraphically higher than the above-mentioned marine band. Above the Worsley Four Foot *A. phillipsi* and its variants are the only known Anthracomyas.

The better known strata from the Arley to the Worsley Four Foot are capable of a broad zonal subdivision comparable with that described by Clift and Trueman for Nottinghamshire and Derbyshire,[1] and by Hopkins[2] for Durham and Northumberland, that is to say the Ovalis, Modiolaris and Pulchra Zones are separable but the Similis Zone of S. Wales[3] cannot be traced. Further subdivisions of the zones can also be effected on a faunal basis, but it is not yet known to what extent these subzones are traceable laterally, though some of them certainly hold for considerable distances within the coalfield itself.

In the 3,300 feet of strata between the Arley Mine and the base of the Phillipsi Zone at the Worsley Four Foot, it so happens that there is a natural triple subdivision, punctuated by two groups of thick workable seams, the Trencherbone Group and the Roger Group. It is not without significance that these coal groups limit the faunal zones, the Trencherbone Group occurring between the Ovalis and Modiolaris Zones, and the Roger Group between the Modiolaris and Pulchra Zones. Only long range forms transgress the vertical limits set by these coal-groups, and even these may on further study prove capable of subdivision.

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[1] Clift, S. C., and A. E. Trueman, 'The Sequence of Non-Marine Lamellibranchs in the Coal Measures of Nottinghamshire and Derbyshire,' *Quart. Journ. Geol. Soc.*, vol. lxxxv, 1929, p. 77.

[2] Hopkins, W., 'The Distribution of the Mussel Bands of the Northumberland and Durham Coalfield,' *Proc. Univ. Durham Phil. Soc.*, vol. viii, 1928, part 1.

[3] Davies, J. H., and A. E. Trueman, 'A Revision of the Non-Marine Lamellibranchs of the Coal Measures, and a Discussion of their Zonal Sequence,' *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927, p. 210.

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In the description of the fauna every endeavour has naturally been made to use the existing nomenclature, but the imperfection of many of the type specimens, the complete loss of others, combined with extremely inadequate descriptions and figuring, make it impossible to get far without establishing new species. It is probable that more of the existing names could have been used if accurate localities and horizons had been cited, because it might then have been possible to obtain topotypes and to re-establish the species on a firm foundation. The localities are, however, extremely vague, generally consisting of the name of a town such as Wakefield, and the horizon is usually given as Coal Measures. The material dealt with by Wheelton Hind[1] is in a better state as regards definition of locality and horizon, but he originated very few new species and gave such a wide interpretation to old ones that it is in most instances futile to continue in his use of the nomenclature. The species described in 1927 by Davies and Trueman[2] from the coalfields of South Wales are accurately horizoned, and, the types being accessible, it is possible to identify a number of them as present in the Lancashire coalfield and others as represented by closely related forms. Davies and Trueman have, however, been very economical in the creation of new species, and there is moreover considerable difference in the known faunas of these two fields. It has therefore become expedient to publish descriptions of a number of types.

Description of Species

Carbonicola boltoni sp. nov.

Plate I, figs. 5, 5A, 5B, 6, 7.

1897. *Tellinomya robusta* H. Bolton. *Mem. Manch. Lit. Phil. Soc.*, vol. xli, No. 6, p. 5, pl.v, figs. 6-8.

Holotypes in Manchester Museum, specimens L. 3492 and 3493, from Watergate Colliery, Middle Hulton, Lancs. Horizon, Middle Coal Measures, above the Cannel Mine.

Paratypes: 48648, He3990, He3997 B., Geological Survey Collection, from above the Cannel or King Mine, Peelwood Colliery, Tyldesley, Lancashire.

As pointed out by Jackson[3] in 1912, these shells are preserved only as casts and appear to be Carbonicolas. The full rounded form of the umbones and their contiguity seem, however, to indicate that the shell was thin. The casts therefore gave a fair idea of the form of the shell. There is much variation in form within the bed, but this may be largely ascribed to distortion by crushing. The truncated

[1] Hind, Wheelton, 'A Monograph on Carbonicola, Anthracomya and Naiadites,' *Palaeontographical Society*, 1894-96.

[2] *Op. cit.*

[3] Jackson, J. W., 'Palaeontological Notes from the Manchester Museum: On Mollusca from the Lancashire Coal Measures,' *Geol. Mag.*, 1912, p. 449.

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appearance of Bolton's types, L.3492-3, is possibly due to the same cause, but the true outline of the lateral view of the shell is probably given by the right valve of L.3493.

Description.—The umbones are full and rounded, and circular or broad oval in horizontal section. The dorsal slope is strongly to gently curved, and sweeps continuously into the ventral margin through a rounded angle of about 60°. The ventral margin is strongly and almost uniformly curved, the point of maximum curvature varying somewhat. It sweeps upward from a point beneath the umbo into the well-rounded and occasionally prominent anterior end, which in its turn meets the slightly re-entrant frontal umbonal slope in a well-rounded obtuse angle.

The shell is extremely broad and stout. The lunule is broad and well marked, both it and the frontal aspect of the shell being gracefully heart-shaped. The maximum width is behind the umbones, about the middle of the length of the shell, and at one-third or less of the height from the umbones. The paratypes are better preserved than the holotypes and should be consulted. They show on the dorsal or posterior umbonal slope a vaguely defined spindle-shaped or elongated heart-shaped area somewhat like the lunule in outline. This may possibly be the escutcheon referred to by Bolton. It is feebly and partially seen on L.3492. A groove extending half-way down the centre of it contains the ligament.

Dimensions* of holotype, L.3493 :—l=32 h=75 t=64 a=37·5
,, paratype, 48648 :—l=28 h=86 t=57 a=32

These specimens are both slightly distorted, a fact which may partly account for the divergence in the measurements; the paratype is probably nearer the true shape.

Range.—This shell is, as far as is known, confined to a limited area of the Cannel Mine in the western part of the Lancashire Coalfield. It is not known in the eastern or Oldham area, in a portion of which, at any rate, sandy strata occur over the equivalent Black Mine.

Carbonicola os-lancis sp. nov.

Plate II, figs. 5, 5A, 5B, 6.

Holotype: 48651. Paratypes: (1), He3030; (2), 48643. All in the Geological Survey Collections.

Description.—A fairly elongate shell, 3-4 cm. in length, characterised by the obliquity of its truncation, which gives to the posterior

* Length (l) absolute in mm.; height (h), width (t), and anterior end (a), as percentages of length.

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end of the shell a bevelled or chisel-like appearance when viewed from the side. The umbones have little prominence and are probably long-ovate in section. The postero-dorsal slope is gently curved and abruptly cut off at an angle of about 140° by the posterior truncation. This is also gently curved and makes with the ventral border a slightly rounded angle of about 60 or 70°. The ventral border is very gently curved or nearly straight at the posterior end, but becomes more curved as it passes forward. The point at which the upward sweep into the frontal lobe begins seems variable in position, and the maximum depth may be behind, under or even in front of the umbo. The frontal lobe is well-rounded and in the types sweeps into the anterior umbonal slope without angulation. The anterior umbonal slope is short and hardly at all re-entrant.

The width of the shell is not accurately known, but cannot have been great. The maximum width is apparently under the umbones, and one-quarter to one-third of the distance from the umbones to the ventral margin.

The shell in most specimens has disappeared, but paratype (1) has sufficient preserved to show that it was thin, and its loss does not seriously affect the form.

Dimensions of holotype :	l=30 h=52 t=20 ?	a=27
,, paratype (1) :	l=29 h=50 t=?	a=27
,, ,, (2) :	l=42 h=48 t=22 ?	a=24

Resemblances.—This shell may be a variant of *C. subconstricta* (J. Sow.), as lectotype of which we take the original of Hind's pl. vii, fig. 6, 1895, regarding fig. 5 as a different form, possibly allied to *C. communis* Davies and Trueman. In *C. os-lancis* the umbo is much less prominent, and the posterior truncation more oblique.

There is some possibility of confusion with *C. venusta* Davies and Trueman, and shells having affinity with the latter occur on the same horizon. The frontal lobe in *C. os-lancis* is rounder and higher, the anterior umbonal slope is shorter and less re-entrant and the posterior truncation is generally more oblique and shorter.

Localities and horizon.—Holotype : Astley Green Colliery, S.E. of Tyldesley, Lancashire. One-inch map 85, six-inch map 102 N.E., from above the Trencherbone Mine, Middle Coal Measures.

Paratype (1) : Lowside Brickworks, Glodwick, S.E. of Oldham, Lancashire. One-inch map 85, six-inch map 97 S.W. Midway between the Blenfire and Oldham Great Mines about 40 feet above the latter.

Paratype (2) : Same locality, about 25–30 feet above the Oldham Great Mine.

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Carbonicola os-lancis, var. *pectorata* var. nov.

Plate II, fig. 7.

Type: 48652, Astley Green Colliery, S.E. of Tyldesley, Lancashire. One-inch map 85, six-inch map 102 N.E., from above the Trencherbone Mine, Middle Coal Measures. In the Geological Survey Collection.

This differs from the more normal individuals of the species in having the frontal lobe much fuller and more rounded so that the greatest depth of the shell tends to be slightly in front of the umbones. The ventral margin is straight or slightly re-entrant towards the posterior end. The relation to the normal type is much the same as that of *C. robusta* Hind (*non* Sow.) to *C. acuta* or *C. subconstricta*.

A closely allied variant exemplified by specimen He4085 in the Geological Survey Collection is almost identical in form with *C. similis* (Brown).

Dimensions of type: l=43 h=53 t=16? a=28

C. elliptica sp. nov.

Plate II, figs. 2, 2A, 2B, 3.

Holotype: 48640, from horizon M.C. 1A 340 feet above the Oldham Great Mine in Moston Colliery, Manchester.

Paratypes: 48639, LT.429, 435, from same locality and bed; LT.361 and 366, horizon M.C. 1, just below M.C. 1A in same locality. All types in the Geological Survey Collection.

Description.—Shell 2 to 2½ cm. in length, of deep oval outline and displaying a variable degree of posterior truncation. Umbones not prominent, umbonal sections probably oval. Dorsal slope very slightly curved, variably passing into or cut off by the posterior margin or truncation at an angle of about 130°. The posterior margin sweeps evenly without noticeable angulation into the well curved ventral margin, and the latter passes equally indefinitely into the well rounded ventral lobe. In solid specimens the frontal margin is cut off at an obtuse angle by the slightly re-entrant frontal umbonal slope, but with progressive crushing this angle and the re-entrant curve of the frontal umbonal slope become obliterated, giving to flattened specimens the appearance of a full and high frontal lobe.

The shell is slightly and evenly tumid, the maximum width being a little behind the umbones and a little more than a third of the depth of the shell below them. The shell substance is not preserved in any of the specimens, but it was probably thin, with delicate lines of growth. These show that the slight posterior truncation tends to increase with maturity.

Dimensions of holotype: l=21 h=71 t=38? a=36.

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Resemblances.—This shell bears a certain resemblance to *C. similis* (Brown), but, if the figure of this properly represents the type, there is not likely to be any confusion, Brown's species having a short posterior truncation and a well-marked posterior-inferior angle.

Horizon and Range.—These and closely related forms occur in great abundance in the lower part of the Modiolaris Zone. They do not appear to range into the upper part of the zone, and are completely absent in the Ovalis Zone below.

Carbonicola cycloquadrata sp. nov.

Plate II, fig. 8.

Type: 48638, from horizon M.C.1, 340 feet above the Oldham Great Mine in Moston Colliery, Manchester. Geological Survey Collection.

Description.—A shell of rounded quadrate form a little over 2 cm. in length, with prominent nearly central umbones. The postero-dorsal slope is straight and short, being abruptly truncated at an angle of about 130° by the long posterior margin, which is gently curved and sweeps through a rounded angle of about 70° into the ventral margin. The latter is gently curved and sweeps upward from a point below the umbo into the blunt and vertically elongated anterior lobe, which is cut off at a level distinctly below the umbo by the slightly re-entrant anterior umbonal slope. Owing to the vertical elongation of the anterior lobe there is a distinct, nearly straight or gently curved frontal margin, which makes a very rounded angle of about 100° with the ventral margin.

Shell with slight and even tumidity, the greatest width being a little behind the umbo and about one-third of the height from it. The shell substance is not preserved on the type but was probably thin. The existing surface is faintly marked with delicate lines of growth, which, except very near the umbo, follow the outline of the shell and show that it took on its characteristic cyclo-quadrate form at an early stage.

Dimensions of type: l=21 h=83 t=38? a=36.

Affinity.—This species is obviously related to *C. dawsoni* (Brown) which occurs about 50 feet higher in the succession. It has somewhat less central umbones and differs completely in contour.

Range.—*C. dawsoni* and *C. cycloquadrata* may be taken as representatives of a group of forms in which the shell approaches circularity, with more central umbones and greater depth than is usual. They are never common, and hitherto have been found only in the lower part of the Modiolaris Zone, in the metals above and below the horizon of the Doe Mine.

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Carbonicola carissima sp. nov.

Plate I, fig. 9, 9A.

Holotype: 48644, from stream sections south of Oaken Bottom Mills, Tonge Fold, south-east of Bolton. One-inch map 85, six-inch map 87 S.W. Just below the Peel Hall Rock.

Metatypes: He2900 and 2902-7, same locality. Paratypes LT.854-858 and 860 from horizon M.C.5. Moston Colliery, Manchester. Just below the Huncliffe Rock. All types in the Geological Survey Collection.

Description.—A small shell about 1 cm. in length. The postero-dorsal slope is gently curved, the greater depth of the shell being a little behind the umbones, sometimes even well behind them, so that the shell becomes in outline almost like an *Anthracomya*. Posterior end definitely truncated, the gently curved truncation making an angle of about 120° with the postero-dorsal slope. The rounded postero-ventral angle is difficult to measure on account of the curving of the truncation: it is about 90° or may be less. The ventral margin is straight or rarely very gently curved. It sweeps up into the frontal lobe from a point under or a little behind the umbones. The frontal lobe is well rounded in outline in its lower portion, but tends to be cut off at an angle somewhat below the level of the umbones, where the surface recedes into the lunule, the anterior umbonal slope being fairly long, re-entrant and well marked in proportion to the size of the shell, but variable. The lines of growth are well defined, sometimes even coarse, and tend to be tilted forward a little near the umbo.

Dimensions of holotype: l=11 h=52 t=45? a=21.

,, paratype (LT.854): l=13 h=55 t=35? a=28

Resemblances.—These small shells approximate to others slightly larger approaching *C. concinna* and *C. aquilina*, which occur on the same horizon. It is conceivable that they are young of these, but they keep fairly well to one size and are abundant and apparently characteristic of one horizon on both sides of the coalfield. The most *Anthracomya*-like forms of this species show an approach to those forms of *A. pulchra* (from below the Roger) which have no marked posterior expansion. There is a certain resemblance to *C. angulata* Hind from the Low Bottom Bed of Burnley, but the marked angulation of the carina characteristic of the latter is absent.

Range.—So far as known, this appears to be confined to two beds within 100 feet vertically of one another. It is useful in that it gives a correlation across the field.

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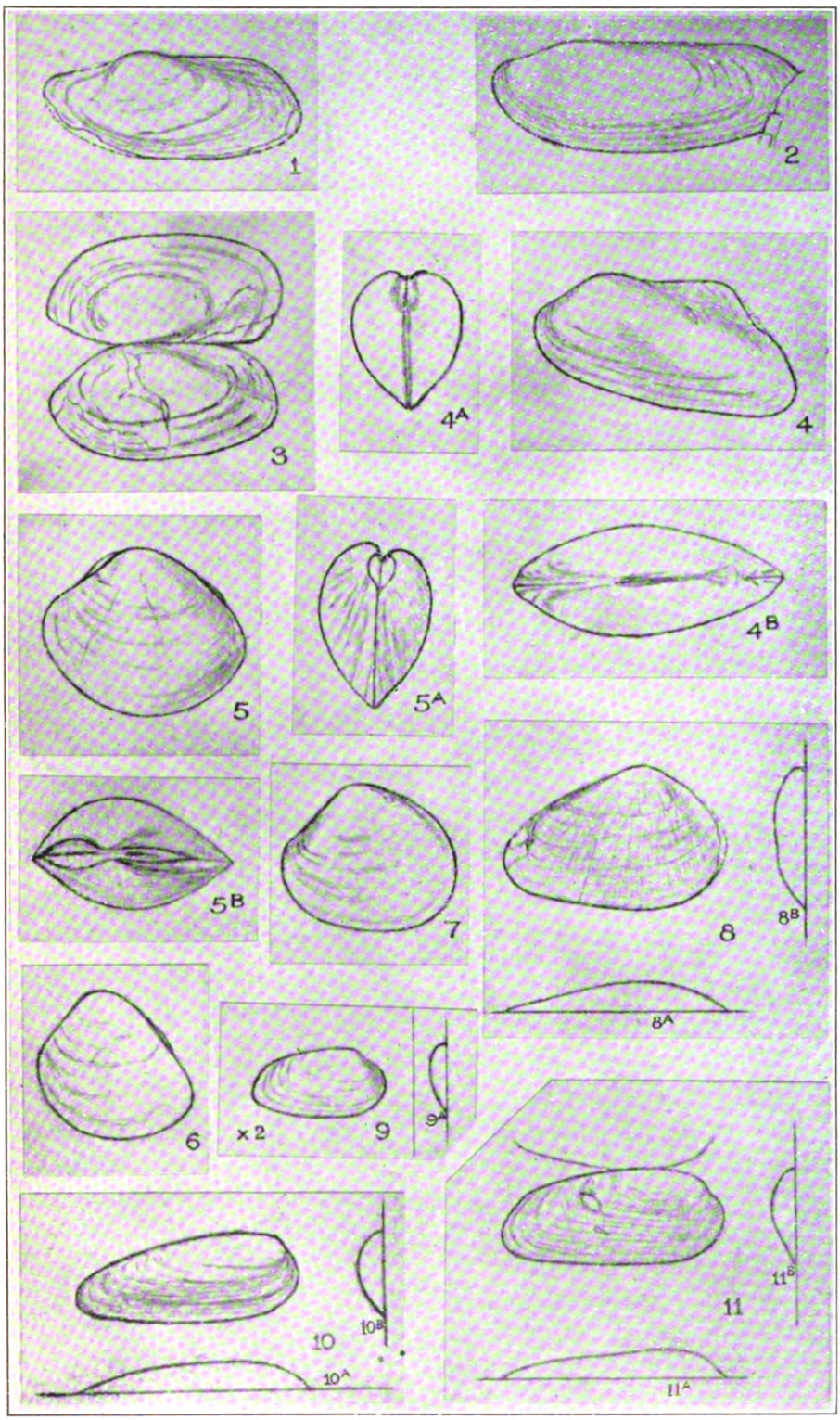

ANTHRACOMYA AND CARBONICOLA

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Carbonicola phrygiana sp. nov.

Plate II, figs. 4, 4A, 4B.

Type in Manchester Museum, E. collection, Wild, W.551, from the Stubbs Mine, Bardsley, Lancashire.

Description.—Umbones prominent, not much, if at all, raised above the hinge line, but tilted forward over the lunule. Dorsal slope notably curved or arched, often rising above the level of the umbones, and sweeping without posterior truncation into the lower border. This border is fairly straight in the posterior half of its length, but sweeps upward from a point well behind the umbones and generally about the middle of the shell into the rounded but rather short anterior lobe. Anterior umbonal slope short but deeply re-entrant. From the margin inward the lines of growth are tilted progressively until, as they approach the umbo, they make a very considerable angle (in the holotype about 40°) with the straighter portion of the lower border.

The shell retains a fairly even width for a considerable part of its length, the maximum width being situated at about a third of the height from the umbo. The umbonal sections are elongated and in the type the umbones are eroded.

Dimensions of holotype: l=43 h=56 t=36 a=15?

Resemblances.—An obvious variant of *C. aquilina* (J. de C. Sow.), from which, however, it differs completely in outline. It has points of resemblance to *C. retrotracta* sp. nov., into which it seems to pass by a series of intermediate forms on the horizon of the latter. The back is more arched than in *C. retrotracta* and sweeps without truncation into the ventral margin. It is also closely related to *C. sulcata* (Brown), but differs markedly in the tilting of the lines of growth, if these are correctly represented in Brown's[1] figure.

Range.—*C. phrygiana* and its allies, all characterised by a strongly arched dorsal slope and highly tilted umbones and lines of growth, appear to be confined to the Modiolaris Zone, having thus a more restricted range than *C. aquilina*.

Carbonicola concinna sp. nov.

Plate I, fig. 11, 11A, 11B.

Holotype: 48645, from above the Ashclough Mine, immediately below the weir, on the south bank of the River Irwell, ½ mile S. of Little Lever, Lancashire. One-inch map 85, six-inch map 95 N.E. In the Geological Survey Collection.

[1] Brown, Capt. Thomas, 'Fossil Conchology of Great Britain and Ireland,' London, 1849, pl. lxxiii, fig. 29.

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An elongated shell of medium to small size attaining a length of 3 cm., but often less. The umbones have very little prominence and the maximum height of the shell may be slightly behind them. The dorsal slope is very gently curved, but does not sweep continuously to the postero-ventral angle, being definitely truncated at an angle of about 140°, the postero-dorsal angle thus formed being slightly rounded off. The height of the shell at its truncation is about two-thirds of its maximum height, so that the dorsal and ventral margins of the shell are slightly convergent. The rounded postero-ventral angle is about 65°. The ventral margin is straight, but begins to sweep upward into the frontal lobe at a point a little behind the umbo. The anterior lobe is short, rounded and high, the anterior umbonal slope being short and only slightly re-entrant. The shell is not very tumid, the maximum width being situated about one-third or more of the height of the shell beneath the umbones, and having a considerable extension backwards from this point along the length of the shell. The umbonal sections are elongate. The surface is marked with faint growth lines not strongly tilted.

Dimensions of type : l=31 h=42 t=22·5 ? a=14·5

Resemblances.—This species is near *C. nitida* Davies and Trueman, but distinguishable by the shorter, more rounded, and higher anterior lobe and slightly curved dorsal slope.

It is also near *C. acutella* sp. nov., but is distinguishable by the marked posterior truncation.

It is also near *C. aquilina* (J. de C. Sow.), of which it is probably a development, but is distinguishable by the shorter, more rounded and higher anterior lobe and the less tilted lines of growth.

Range.—*C. concinna* enters about the middle of the Modiolaris Zone and ranges up into the middle of the Pulchra Zone. The type comes from the top of its range.

Carbonicola acutella sp. nov.

Plate I, fig. 10, 10A, 10B.

Holotype : 48647, from above the Ashclough Mine immediately below the weir, on the south bank of the River Irwell, ½ mile S. of Little Lever, Lancashire. One-inch map 85, six-inch map 95 N.E.

Paratypes : He2987 and 2982, from the same locality. All types are in the Geological Survey Collection.

Description.—An elongated shell of comparatively small size, attaining a length of over three centimetres but often two or less. The umbones have very little prominence, the greatest depth of the shell being often posterior to them. The dorsal slope is gently curved, the curvature extending to the pointed posterior end which shows little or no truncation. The ventral margin is nearly straight

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in its posterior portion, the straightness continuing for two-thirds of the length, but curves gently upwards into the rounded anterior lobe. The anterior lobe is short and high, the anterior umbonal slope being short and only slightly re-entrant. The surface is marked with faint lines of growth, not noticeably tilted except possibly near the umbo, where they are usually obscure. The shell is evenly tumid, the position of maximum thickness being situated a little behind the umbones but having a considerable extension backwards from this point along the length of the shell. It is slightly nearer to the umbo than to the ventral margin.

Dimensions of holotype: l=32 h=37·5 t=28 a=11·5

Resemblances.—Wheelton Hind figures no species with which this can be compared. He would no doubt have regarded it as a variant of *C. aquilina*. Brown figures nothing resembling it, nor do Davies and Trueman.

It may be closely allied to *C. concinna* sp. nov., but is distinguished by the absence of a posterior truncation.

Range.—Horizon B.C.7, Bradford Colliery, Manchester, 100 feet above the Bradford Top Mine, and horizon M.C.12 of Moston Colliery, Manchester, are without question identical one with the other, and with the bed above the Ashclough Mine from which the type material is derived. They yield *C. acutella* in abundance. Identical or closely related forms are found in Bradford Colliery on horizons B.C.6 and B.C.5, approximately 100 and 150 feet above the type horizon; they are, however, not common and are doubtfully if at all represented at the same levels at Moston Colliery. Allied forms also occur fairly commonly some 400 feet below the type horizon in the well known shell beds between the Top Furnace and Roger Mines of Oldham (M.C. 7 and 8). They have not been proved in any intermediate beds. The shell thus ranges throughout the greater part of the Pulchra Zone and is confined to it.

Carbonicola radiata sp. nov.

Plate I, fig. 8, 8A, 8B.

Holotype: 48641. Paratypes: LT. 1470 and 1464, all from the return airway in Bradford Colliery, Manchester, horizon B.C.7, 100 feet above the Bradford Top Mine. Geological Survey Collection.

Description.—A robust shell of ordinary elongation, generally about 3 cm. in length. Umbones fairly prominent. Umbonal sections ovate. Dorsal slope gently curved and making an angle of about 40° with the posterior half of the ventral margin, into which it sweeps gradually with little or no truncation. Ventral margin curved throughout, but less so posteriorly and sweeping up from a

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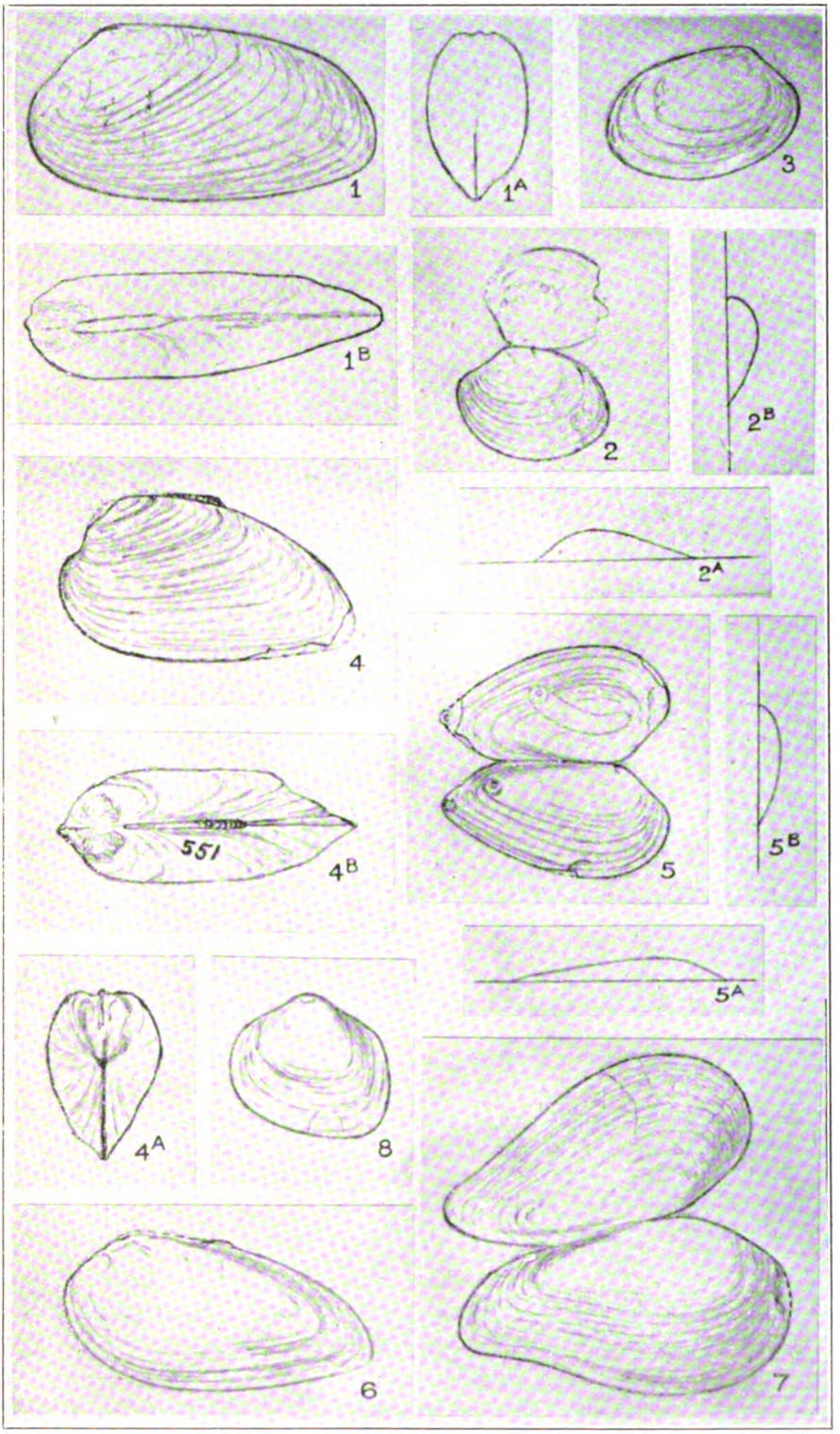

CARBONICOLA

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point beneath or behind the umbo into the rounded and fairly high anterior lobe. Anterior umbonal slope of moderate length and only slightly re-entrant.

Shell not very tumid, the maximum width being situated beneath the umbones and more than one-third of the height of the shell from them. The shell substance is thick and apparently consists of two layers of calcite. When the outer is stripped off the inner is seen to be distinctly striated in a radial direction. This striation is sometimes rather feebly displayed on the inner and outer surfaces. The lines of growth appear to maintain their parallelism with the ventral border almost if not quite into the umbones.

Resemblances.—*Carbonicola obtusa* Hind (1895, pl. vii, fig. 16) from the Lower Coal Measures of N. Staffordshire, is fairly comparable with *C. radiata* in general form, but there is no sign of radial striation in Hind's species.

Range.—As far as is known this species is confined to a single horizon. It is found again at this same horizon (M.C.12) in Moston Colliery, Manchester, and occurs also in the bed above the Ashclough Mine in the Bolton Area, and again at 330 feet in Moston Mill Borehole.

Anthracomya fisheri sp. nov.

Plate I, fig. 4, 4A, 4B.

Type: 48653. From above the Doe Mine, Pendleton Colliery, Lancashire, in the collection of the Geological Survey. Presented by Mr. F. H. Fisher, Manager of Bradford Colliery, Manchester.

Description.—A tumid shell with the maximum depth definitely at the posterior end. Umbones swollen and rising somewhat above the hinge line. Hinge line about half to three-fifths of the total length of the shell, fairly sharply cut off at an angle of 120–130° by the posterior margin. The latter is straight or slightly curved, passing with a rounded angle of 40 or 50° into the almost straight ventral margin, which is inclined to the hinge line at an angle of about 15° but sweeps upward from a point below the umbones into the rounded frontal lobe. The frontal margin passes without noticeable angulation into the almost straight frontal umbonal slope at a level slightly below the hinge line.

A well marked broadly swollen carina passes from the umbones obliquely backwards, bowing slightly forwards as it passes on to the sides of the shell and thence again backwards to reach the margin of the shell at the postero-ventral angle, losing definiteness as it goes. The greatest thickness is well behind the umbones a little in advance of the middle of the shell and about one-third of the total height from the umbones.

In front of the carina there is a slight constriction which broadens out and disappears before it reaches the straight ventral margin.

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Dimensions of type[1]: l=37 h=50 t=40·5 a=24 u=81 α=30–35° β=120–130°

Resemblances.—This species is near *A. insignis* Davies and Trueman, but is distinguished readily by the course of the carina, which does not reach the ventral margin in advance of the posterior inferior angle. This latter angle is also more acute than in *A. insignis*.

The straightness of the lower border and the acuteness of the posterior inferior angle separate this species from *A. robertsoni* (Brown).

The specimen figured by Hind, 1895, pl. xvi, fig. 53, from the Grains Ironstone, Dudley, South Staffordshire, is very near *A. fisheri*, and specimen LT.537 (Geological Survey Collection) from horizon M.C.2B, Moston Colliery, Manchester, 400 feet above the Oldham Great Mine, shows an approach to this species, but has a longer hinge line and a less acute posterior inferior angle. The latter character is, however, intensified in appearance if not entirely produced by crushing.

Anthracomya oblonga sp. nov.

Plate I, fig. 2.

Type: 48637, from horizon M.C.11 about 200 feet above the Roger Mine in Moston Colliery, Manchester. In the Geological Survey Collection.

Description.—An elongated anthracomyaform shell with straight hinge-line, and the greatest depth just behind the umbones, a little more than one-third of the length of the shell from the anterior end. The growth lines of the very rounded posterior end make an angle of more than 150° with the hinge-line, so that there is practically no truncation. There is no postero-ventral angle, the posterior margin passing with nearly constant curvature into the more gently but evenly curved ventral margin. The latter sweeps upward in a steady curve from the point of maximum depth a little behind the umbones into the frontal lobe, the margin of which meets the very slightly re-entrant anterior umbonal slope in a fairly sharp angle not far below the level of the umbones. The umbones are inconspicuous and rise little if at all above the hinge-line. The postero-dorsal slope shows slight radial striation.

Dimensions of type: l=42 h=36 t=? a=24 u=91 α=10° or less β=150° or more

Resemblances.—This species is quite distinct from any hitherto described. It has up to the present only been obtained from horizon

[1] The letters l, h, t, a, have the same significance as in descriptions of *Carbonicola*; u is the ratio of the umbonal to the maximum depth expressed as a percentage, α is the angle between the hinge line and the line joining the umbo to the posterior-inferior angle, and β is the postero-dorsal angle.

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M.C.11, Moston Colliery, Manchester, about 200 feet above the Roger Mine. The maximum depth is further forward than in the other two members of the *librata* group.

Anthracomya librata sp. nov.

Plate I, fig. 3.

Holotype: 48646. Topotype: He2983, from above the Ashclough Mine immediately below the weir, on the south bank of the River Irwell, ½ mile S. of Little Lever, Lancashire. One-inch map 85, six-inch map 95 N.E.

Paratype A. (LT.1222) from horizon M.C.12, Moston Colliery, Manchester.

Paratype B. (LT.1491) from horizon B.C.7, Bradford Colliery, Manchester.

All types in the Geological Survey Collection.

Description.—Shell of anthracomyaform type with straight hinge-line. Umbones rounded and not prominent, a little less than one-third of the length of the shell from the anterior end. Posterior superior angle slightly rounded and having a value of about 110°. Truncation of posterior margin gently curved, meeting the well curved ventral margin in a rounded posterior inferior angle almost impossible to measure, but roughly about 80 or 90°. Maximum depth about the middle of the shell. Ventral margin well curved, sweeping upwards from a point well behind the umbones into the rounded, prominent, and fairly high anterior lobe, the upper margin of which is formed by the slightly re-entrant anterior umbonal slope. The known specimens are somewhat flattened on shale, so that the plan and elevation cannot yet be described. Carina slight, if any.

Dimension of type: l=32 h=50 t=? a=27 u=90 α=23° β=110°

,, topotype: l=34 h=50 t=? a=29 u=94

Resemblances.—This is the best established of a group of species including also *A. oblonga* sp. nov. and *A. cymbula* sp. nov., which appear for the first time in beds above the Roger Mine, that is to say in the lower part of the Pulchra Zone. These species agree in the possession of a well curved lower margin and in the forward displacement of the point of maximum depth in comparison with its position in species occupying a lower horizon. The only comparable figured specimens are the type of the extremely doubtful species *A. wardi* Etheridge (Hind, 1895, pl. xv, fig. 14), a second specimen of which has never been found, and that figured by Hind from the Burnwood Ironstone (1895, pl. xv, fig. 15), a thousand feet higher than *A. wardi* Etheridge. The maximum depth is further forward in *A. librata* than in either of these.

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Anthracomya cymbula sp. nov.

Plate I, fig. 1.

Type: 48636, from horizon M.C.12, about 340 ft. above the Roger Mine, Moston Colliery, Manchester. In Geological Survey Collection.

Description.—An elongated anthracomyaform shell with the maximum depth about two-thirds of the length of the shell from the anterior end. Umbones rounded, fairly prominent, rising slightly above the hinge-line. Posterior margin or truncation making a slightly rounded angle of about 130° with the hinge-line, and sweeping with a well rounded angle of 50–70° into the well curved ventral margin. The ventral margin sweeps upward from a point about the middle of the shell towards the acutely rounded and shallow anterior lobe, the upper margin of which lies well below the umbones, and hinge-line, the anterior umbonal slope being markedly re-entrant. There is little or no carina and the postero-dorsal slope is radially striated.

Dimensions of type: l=35 h=40 t=27? a=26? u=91 α=16° β=130°

Resemblances.—*A. cymbula* somewhat resembles and is possibly allied to *A. lanceolata* Hind. The posterior margin or truncation is however, longer, so that the postero-ventral angle is not so near the hinge-line and the angle α is 16° instead of 10°. The anterior lobe is probably also a little longer. This species has also been found in the equivalent horizon (B.C.7) in Bradford Colliery.

Faunal Succession

The Ovalis Zone

With the above additions to the existing nomenclature it is now possible to summarize briefly the main faunal variations within the Manchester succession. The Ovalis Zone extends from below the Arley to the Cannel Mine (=Black of Oldham). The narrow belt between the Cannel and Trencherbone is in doubt, as none of the forms characteristic of that zone and restricted to it, such as *Carbonicola ovalis* (Martin), *C. centralis* (J. de C. Sow.), *C. robusta*, Hind (*non* J. de C. Sow.), have been found above the Cannel. The upper limits of *C. communis* Dav. and Tru. and *C. subconstricta* (J. Sow.) are not yet exactly determined, but Carbonicolas allied to these forms occur in this belt and also above the Trencherbone. The remarkable shells described above as *Carbonicola boltoni* sp. nov. occur in the debatable horizon in the roof of the Cannel Mine. They are not found in the east of the coalfield and may be entirely local in their distribution. Miss Emily Dix, however,

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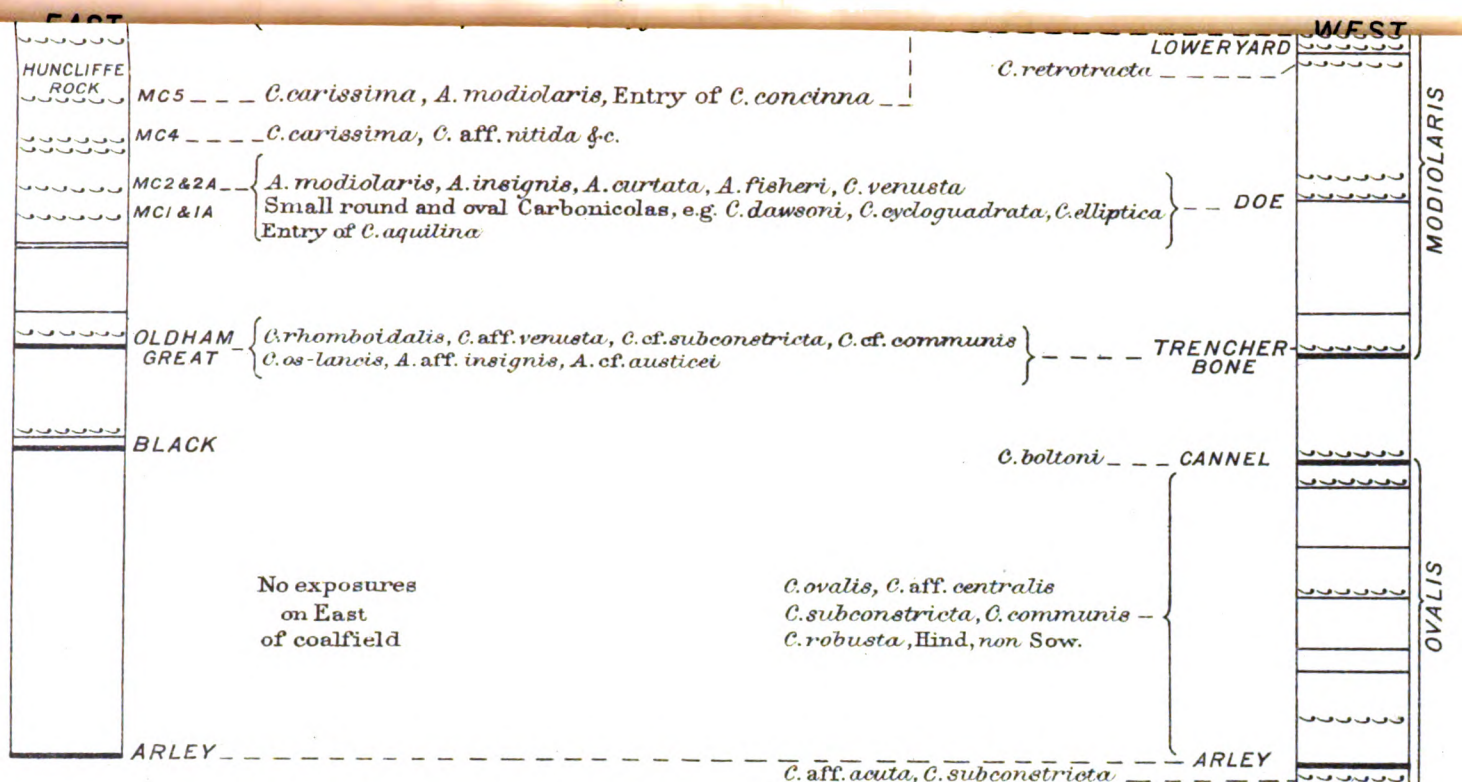
EAST
WEST
HUNCLIFFE ROCK
MC5 — C. carissima, A. modiolaris, Entry of C. concinna
MC4 — C. carissima, C. aff. nitida &c.
MC2&2A — A. modiolaris, A. insignis, A. curtata, A. fisheri, C. venusta
MC1&1A — Small round and oval Carbonicolas, e.g. C. dawsoni, C. cycloquadrata, C. elliptica
Entry of C. aquilina
DOE
OLDHAM GREAT — C. rhomboidalis, C. aff. venusta, C. cf. subconstricta, C. cf. communis
C. os-lancis, A. aff. insignis, A. cf. austicei
TRENCHER BONE
BLACK
No exposures on East of coalfield
C. ovalis, C. aff. centralis
C. subconstricta, C. communis
C. robusta, Hind, non Sow.
ARLEY
C. aff. acuta, C. subconstricta
LOWER YARD
C. retrotracta
C. boltoni
CANNEL
MODIOLARIS
OVALIS

DIAGRAM SHOWING THE ZONAL SUCCESSION IN THE COAL MEASURES AROUND MANCHESTER.

Eastern section to scale; Western not to scale.

Faunas are connected by broken lines to the beds in which they have been proved. Those proved on both sides of the coalfield are connected to both sections.

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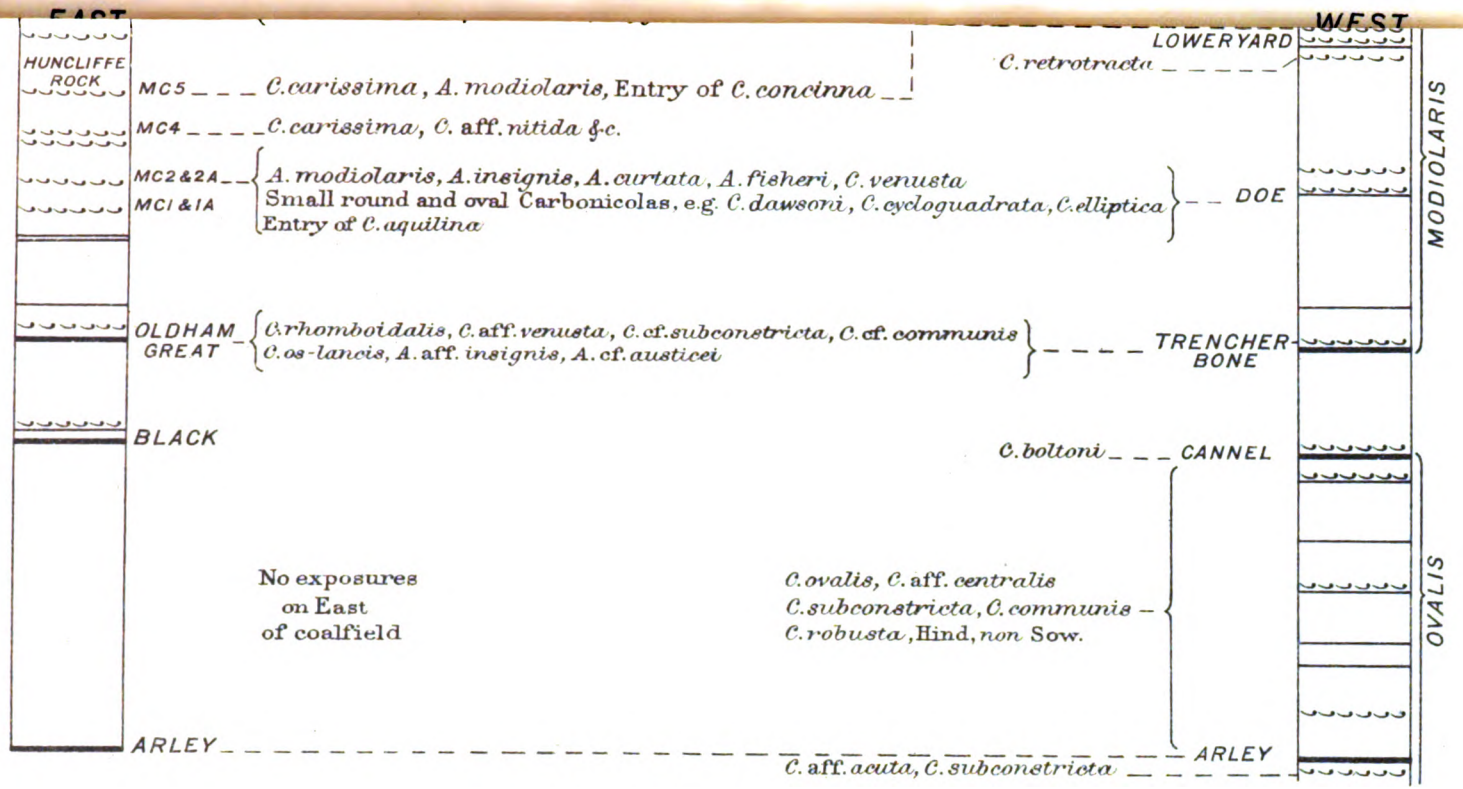
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TRENCHER BONE
BLACK
C. boltoni — CANNEL
No exposures on East of coalfield
C. ovalis, C. aff. centralis
C. subconstricta, C. communis
C. robusta, Hind, non Sow.
OVALIS
ARLEY
ARLEY
C. aff. acuta, C. subconstricta

DIAGRAM SHOWING THE ZONAL SUCCESSION IN THE COAL MEASURES AROUND MANCHESTER.

Eastern section to scale; Western not to scale.

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Anthracomya cymbula sp. nov.

Plate I, fig. 1.

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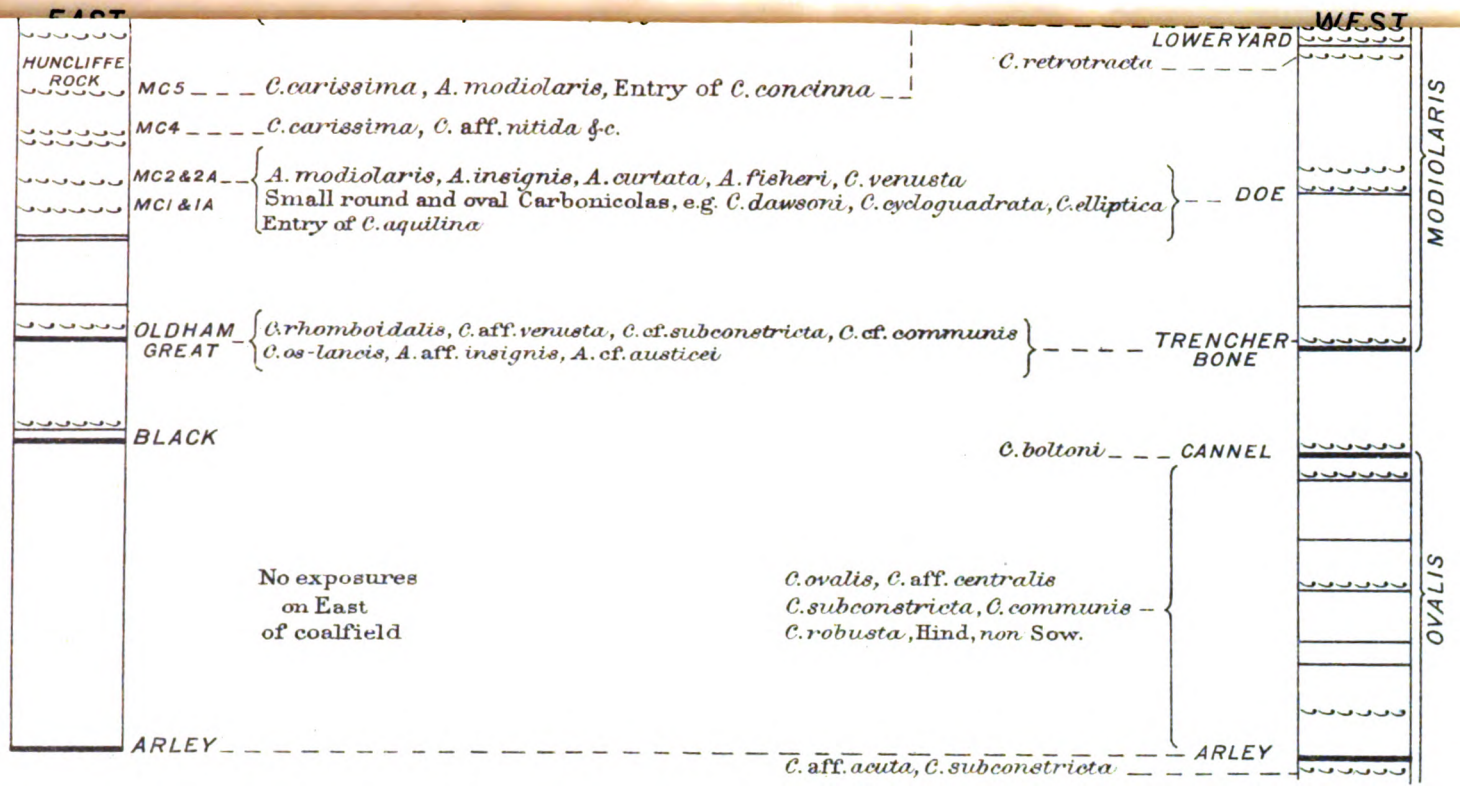

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Eastern section to scale; Western not to scale.

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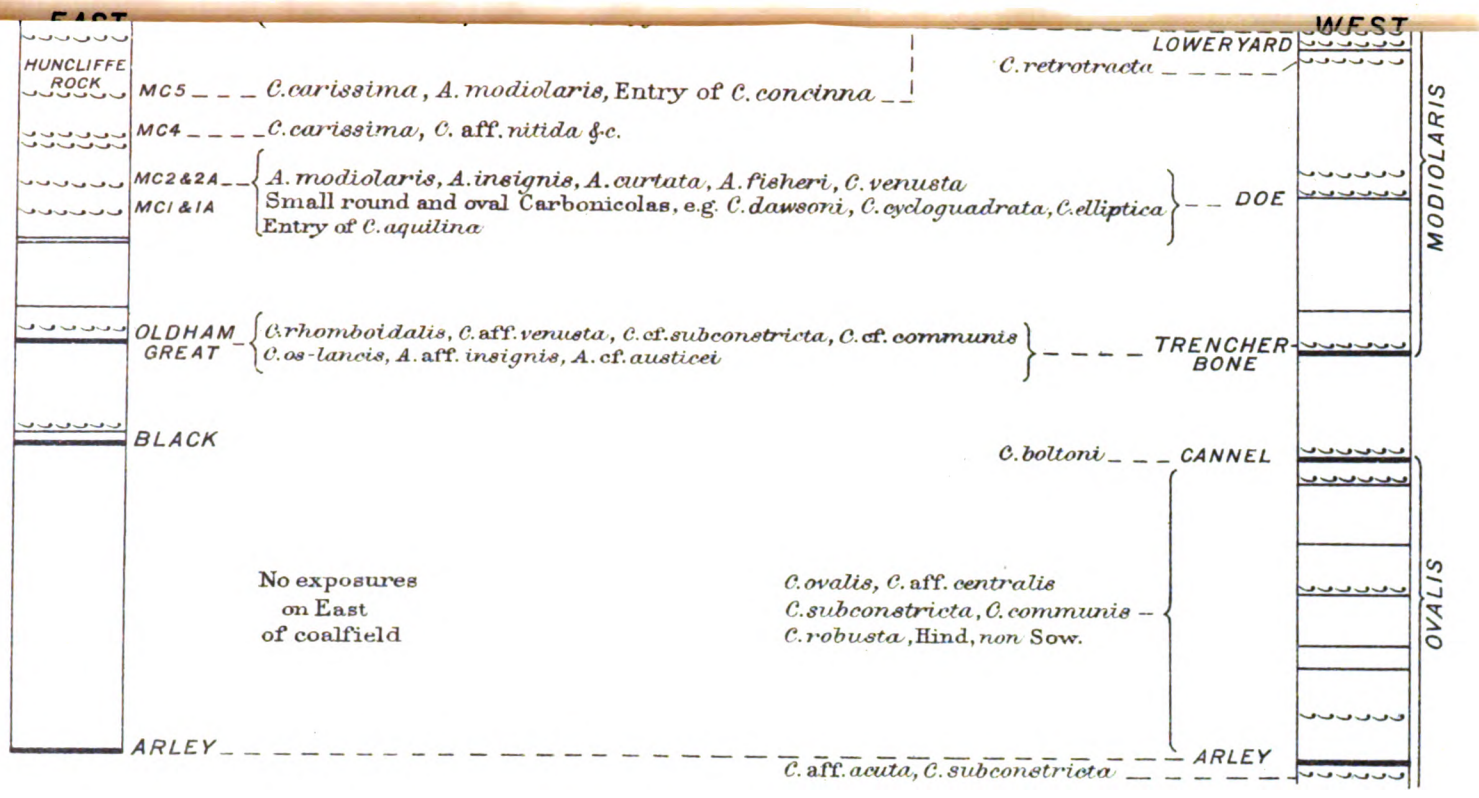

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Eastern section to scale; Western not to scale.

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Plate I, fig. 1.

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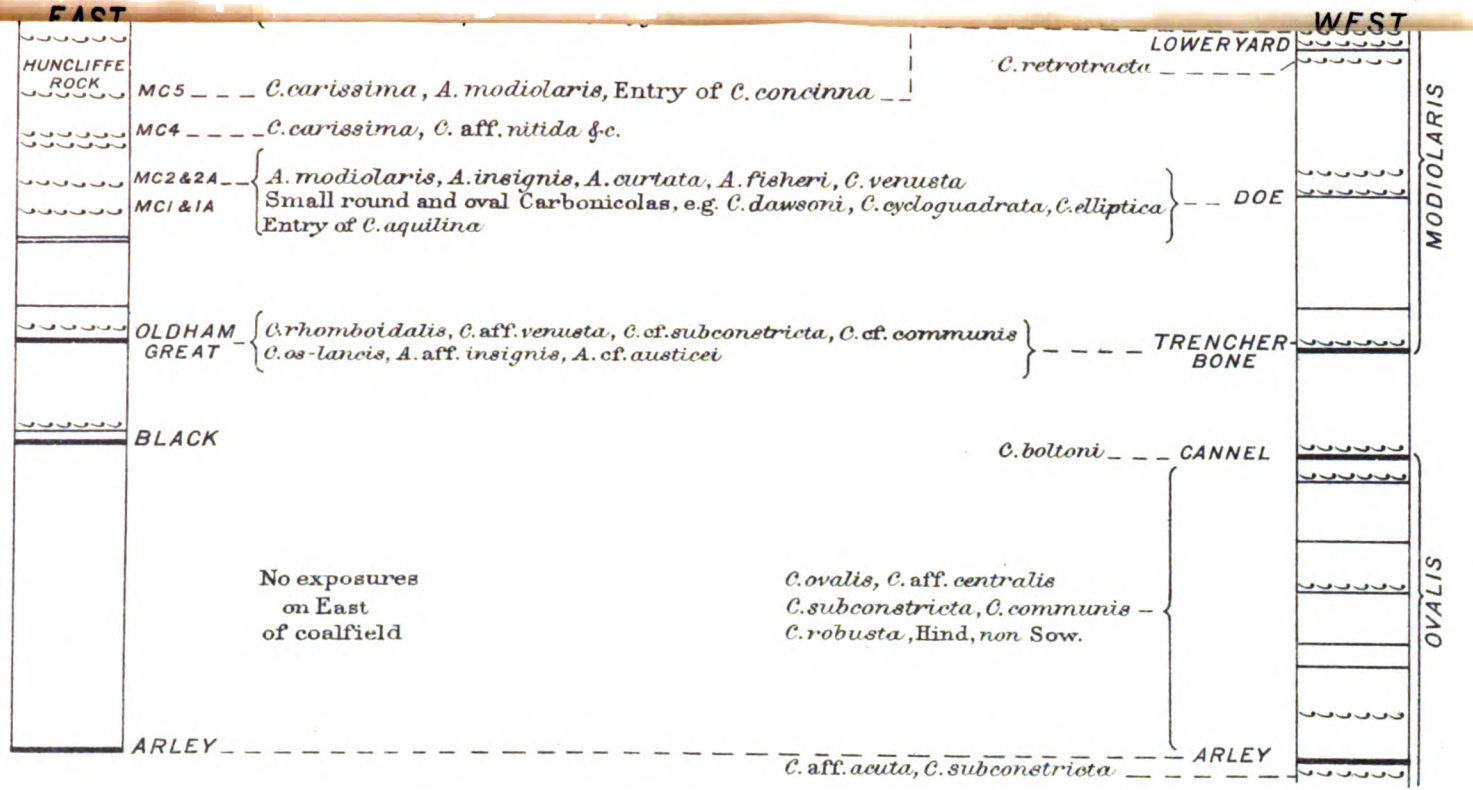
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BLACK
ARLEY
No exposures on East of coalfield
LOWER YARD
C. retrotracta
DOE
TRENCHER BONE
C. boltoni
CANNEL
C. ovalis, C. aff. centralis
C. subconstricta, C. communis
C. robusta, Hind, non Sow.
ARLEY
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MODIOLARIS
OVALIS

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figures a closely similar shell from the top of the Ovalis Zone in South Wales.[1]

THE MODIOLARIS ZONE

The Trencherbone (=Oldham Great Mine) very definitely marks the base of the Modiolaris Zone, being characterised by an invasion of Anthracomyas allied to this species, such as *A.* aff. *insignis* Dav. and Tru. and other forms at present undescribable owing to poorness of material. *A. modiolaris* itself appears a little higher, and, in the Doe Mine some 300 feet above the Trencherbone, the *modiolaris*-fauna attains its greatest strength with *A. modiolaris* (J. de C. Sow.), *A. curtata* (Brown), *A. insignis* Dav. and Tru., and *A. fisheri* sp. nov. *A. modiolaris* extends upwards to the Stubbs Mine, in the roof of which it is found accompanied by *A.* aff. *robertsoni* (Brown). Whether it reaches further up above the Rams and Furnace Mines into the base of the Pulchra Zone must at present remain in doubt. The well known bed between the Furnace and Roger Mines on the east of the coalfield which marks the entry of *A. pulchra*, yields also a small form, which there is some difficulty in separating from *A. modiolaris*, as that species is at present defined, but it is not typical *A. modiolaris*. I have shown this shell to Dr. Trueman and he is of opinion that it is more allied to the *pumila*-group, of which I have little knowledge. At any rate *A. modiolaris* does not appear to extend above the Roger Mine.

The Modiolaris Zone is equally well characterised by its Carbonicolas. Here *C. aquilina* appears for the first time, being the lowest *Carbonicola* in the succession with a notably straight lower border. With many variations in form it ranges up from the Doe Mine right through the Modiolaris Zone at least into the middle of the Pulchra Zone. One of its most marked variants, now separated off as *C. phrygiana*, characterises the middle and upper beds of the Modiolaris Zone. Extremely elongate forms of this species, comparable with *C. lateralis* (Brown) occur on the horizon of the Doe Mine and also in the roof of the Rams, some 600 feet higher. They probably have a long range.

The lower half of the Modiolaris Zone has in addition a number of small rounded oval forms such as *C. dawsoni* (Brown), *C. cyclo-quadrata* and *C. elliptica*. These and *C. venusta* Dav. and Tru. are especially characteristic of the beds about the horizon of the Doe Mine. Below the Peel Hall Rock in the western part of the field a remarkable form now named *C. retrotracta* has a limited range and appears to be confined to the metals in the neighbourhood of the Lower Yard Mine. It might be briefly described as a large and highly steatopygous form of *C. aquilina*. This form is absent in the east. Higher still in the upper third of the zone occur forms which

[1] Dix, Emily, 'The Coal Measures of the Gwendraeth Valley and adjoining Areas,' *Proc. S. Wales Inst. of Engineers*, vol. xliv, 1928, p. 460.

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recall the fauna of the Peacock or Brass Vein of South Wales, including *C. turgida* (Brown), *C. exigua* Dav. and Tru., *C. affinis* Dav. and Tru., and *C. sp. nov.* cf. *fusca* Dav. and Tru. These forms are especially characteristic of the roof of the Stubbs Mine in the eastern part of the field, but elsewhere this eminently recognisable horizon is cut out by sandstone.

At the same level as *C. retrotracta* occurs a remarkable little shell of restricted range, described above as *C. carissima*, which, unlike those just mentioned, gives a means of correlation across the field, occurring in abundance in horizon M.C.5, 600 feet above the Oldham Great Mine in Moston Colliery, Manchester and also below the Peel Hall Rock in the west. There is some doubt as to whether this should be classed as a *Carbonicola* or an *Anthracomya*. This same bed shows the first appearance of *C. concinna*, a form possibly allied to *C. nitida* Dav. and Tru., and ranging from this level up to the Ashclough Mine in the middle of the Pulchra Zone.

THE PULCHRA ZONE

The entry of *Anthracomya pulchra* Hind occurs in a bed well known on the eastern side of the field as lying between the Furnace and Roger Mines, where this species occurs in great profusion along with *Carbonicola concinna*, *C. aquilina*, *C.* aff. *turgida* and *C. acutella*, this last species making its first doubtful appearance at this level. This fauna has up to the present been located only in the eastern half of the field, where, however, it forms a valuable index-horizon. A little higher, in beds extending from the Roger to the roof of the Ashclough Mine, a fauna of larger Anthracomyas makes its appearance. These are quite distinct from the forms of the Modiolaris Zone below, being characterized by a well curved lower margin and a more forward position of the maximum depth of the shell. Among these are *A. oblonga*, *A. librata* and *A. cymbula*. *A. librata* has been found on both sides of the field. *A.* aff. *pulchra* and *A.* aff. *pumila* extend up to about 200 feet above the Roger Mine, but no Anthracomyas except *A. minima* have been found in the next 600 feet of strata extending from the Ashclough Mine to the Dukinfield Marine Band.

The Ashclough Mine is an important horizon which can be identified in both the east and west of the field. The coal with which it is associated in the east has no name. The fauna is a varied one, and embraces *C. fulva*, *C. acutella*, and *C. radiata*, which, so far as known, is confined to the horizon, *C. concinna*, *C.* cf. *nana* (Brown), *C. aquilina*, *A. cymbula*, *A. librata*, *A. minima* and *Naiadites spp. nov.*

Above the Ashclough Mine horizon the fauna becomes greatly impoverished. Species of *Anthracomya*, with the exception of *A. minima*, are wanting, and the Carbonicolas are represented by *C. fulva* and *C. acutella*, with possible doubtful variants of *C. aquilina*. *C. fulva* extends to 320 feet below the Dukinfield Marine Band, and the only known *Carbonicola*-band above this level is some 120 feet

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higher and contains an impoverished fauna of unidentifiable Carbonicolas, possibly *C. aquilina*, with *A. minima*. The occurrence of a strongly winged *Naiadites* in horizon B.C.3, 320 feet below the Marine Band, may be of zonal importance, as it is unknown at any other level.

The *Naiadites* of the Coal Measures present a rather difficult problem. There is unquestionably a much greater variety of form than has hitherto been described, and the existing nomenclature is entirely inadequate. No significance has for instance been attached hitherto to the presence or absence of an ear or wing at the postero-dorsal angle. All figured species are without it except *N. quadrata*, but winged forms indistinguishable in general outline from *N. modiolaris*, *N. carinata*, etc., also occur. The wing is not generally present in the early stages of growth and may or may not develop at maturity. The presence of an extremely pronounced wing seems to be peculiar to the upper beds of the Pulchra Zone, the above-mentioned horizon B.C.3 in Bradford Colliery, Manchester, yielding a form very remarkable in this respect. The material available is too imperfect for the establishment of a species.

Another character not noted in any described form of *Naiadites* is the presence of a posterior angulation of the margin and growth lines midway between the dorsal and ventral angles. *Naiadites* with this character range from the Cannel Mine to below the Peel Hall Rock, and, as far as known, are thus limited to the Modiolaris Zone, with extension into the debatable ground between this and the Ovalis Zone.

The Dukinfield Marine band has only been seen on the eastern side of the Lancashire Coalfield, and no fossil bands for a distance of 2,000 feet above it are known in this district. Direct palaeontological correlation with the west therefore fails at this point. Starting with the identifiable Ashclough Mine as a basis, however, stratigraphical considerations make it apparent that the Parker Mine of Bradford Colliery, which is 200 feet above the marine band, is the Worsley Four Foot of the west. Below the Worsley Four Foot occurs a bed with large species of *Anthracomya*. Of these no determinable specimens have yet been obtained, but two of them recall in their general shape species figured by Wheelton Hind[1] from the Burnwood Ironstone above the Gin Mine Marine Band of North Staffordshire. This is probably the locality given by Hind as Prestolee, from which he figures under the name of *N. elongata* an unquestionable *Anthracomya* of *pulchra* type. *A. pulchra* therefore appears to recur in Lancashire at this horizon. The type material comes from the Burnwood Ironstone. The locality therefore is worthy of further investigation, since it affords an opportunity of testing on external evidence the supposed identity of the Dukinfield and Gin Mine Marine Bands. The evidence available at present favours this correlation.

[1] Hind, Wheelton, *op. cit.*, 1895, pl. xii, fig. 1 ; pl. xv, fig. 15.

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THE PHILLIPSI AND TENUIS ZONES

This upper fauna of large Anthracomyas with associated forms comparable with *A. pulchra* does not extend above the Worsley Four Foot. It marks the top of the Pulchra Zone of Davies and Trueman, and above this last mentioned seam we find ourselves in the base of the immense zone of *A. phillipsi*. This form appears, doubtfully, close above the seam and is found in full development some 40 or 50 feet above it. It appears to occupy this bed to the exclusion of all other forms of mollusca, and crushed specimens show a good deal of variation in outline, one variant of subcircular shape being worthy of mention, as it may possibly characterise the horizon.

Above this level, until we reach the Upper Coal Measures, present exposures are wanting and records are few. Walcot Gibson has recorded the occurrence of *A. phillipsi* in Rayner's Borehole about 1,000 feet above the position of the Worsley Four Foot, and it is also recorded from the roof of the Bradford Four Foot. In the Ardwick Series both *A. phillipsi* and *A. tenuis* are present, the latter being represented by some specimens from Plymouth Grove Boring, Manchester, preserved in the Manchester Museum. It has also been found by Mr. L. H. Tonks at 344 feet in the Seedley boring in Manchester.

The species described in this paper cover only a portion of the new material assembled in the course of the re-survey of the Manchester district. They have been chosen with great deliberation, having regard for their zonal importance, distinctive character and state of preservation. Dr. Trueman has been kind enough to spend some time in discussing this matter of selection with the writer, and has made valuable suggestions. He has also given every facility for ensuring that the use of specific names of earlier date is in conformity with his own practice. Miss Dix of University College, Swansea, has also taken much trouble with the same object in view. Any attempt to subdivide the group of *A. phillipsi* has been avoided, as Miss Dix and Dr. Trueman have in hand the revision of this group on the basis of material very superior to any obtained up to the present in Lancashire. Dr. J. W. Jackson has kindly given access to the extensive collection of the Manchester Museum, which contains a number of valuable types and figured specimens.

The zonal results discussed are the outcome of much energetic search for fossils on the part of the geologists of the Lancashire unit, and the stratigraphy which forms its basis has been entirely evolved by them. To Mr. L. H. Tonks who, in the use of *Carbonicola*-bands for the identification of strata, first broke ground in Lancashire with his brilliant and economically important correlation of the Bradford and Oldham fields, the writer's acknowledgments are especially due.

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Explanations of Plates I and II

The specimens illustrated in these plates are in the collection of the Geological Survey in London, except the original of Plate II, fig. 4, in the Manchester Museum. In all cases the register numbers of the specimens are cited, and these give reference to the particulars of locality and horizon in the descriptive text. All the figures are drawn in natural size except Pl. I, fig. 9.

Plate I

Fig.

1. *Anthracomya cymbula* sp. nov., type, 48636.
2. ,, *oblonga* sp. nov., type, 48637.
3. ,, *librata* sp. nov., holotype, 48646.
4. ,, *fisheri* sp. nov., type, 48653.
4A. ,, ,, front view of the same specimen.
4B. ,, ,, dorsal view of the same specimen.
5. *Carbonicola boltoni* sp. nov., paratype, 48648.
5A. ,, ,, front view of the same specimen.
5B. ,, ,, dorsal view of the same specimen.
6. *Carbonicola* aff. *boltoni* sp. nov., extreme variant, 48650.
7. *Carbonicola* aff. *boltoni* sp. nov., extreme variant, 48649.
8. ,, *radiata* sp. nov., holotype, 48641.
8A. ,, ,, longitudinal profile of the same specimen.
8B. ,, ,, vertical profile of the same specimen.
9. ,, *carissima* sp. nov., holotype, x 2; 48644.
9A. ,, ,, vertical profile of the same specimen.
10. ,, *acutella* sp. nov., holotype, 48647.
10A. ,, ,, longitudinal profile of the same specimen.
10B. ,, ,, vertical profile of the same specimen.
11. ,, *concinna* sp. nov., holotype, 48645.
11A. ,, ,, longitudinal profile of the same specimen.
11B. ,, ,, vertical profile of the same specimen.

Plate II

Fig.

1. *Carbonicola retrotracta* sp. nov., holotype (much idealized), 48642.
1A. ,, ,, front view of the same specimen.
1B. ,, ,, dorsal view of the same specimen.
2. ,, *elliptica* sp. nov., holotype, 48640.
2A. ,, ,, longitudinal profile of the same specimen.
2B. ,, ,, vertical profile of the same specimen.
3. ,, ,, paratype, 48639.
4. ,, *phrygiana* sp. nov., type, W.551, E. coll. Wild (Manchester).
4A. ,, ,, front view of the same specimen.
4B. ,, ,, dorsal view of the same specimen.
5. ,, *os-lancis* sp. nov., holotype, 48651.
5A. ,, ,, longitudinal profile of the same specimen.
5B. ,, ,, vertical profile of the same specimen.
6. ,, ,, paratype, 48643.
7. ,, ,, var. *pectorata* var. nov., type, 48652.
8. ,, *cycloquadrata* sp. nov., type, 48638.

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V.—FLORA AND STRATIGRAPHY OF THE BRISTOL AND SOMERSET COALFIELD

By R. Crookall, Ph.D.

Text-figures 1 and 2.

I. Introductory

The Bristol and Somerset Coalfield is of great interest,

(1) as including the type area of the Radstockian Series,

(2) as a field in which the Transition or Staffordian Series—now widely recognised in the British Coal Measures—is well developed,

(3) as an area in which the plant remains acquire additional stratigraphical importance from the fact that animal remains are comparatively scarce and restricted in distribution,

(4) as the strata associated with the Radstock Series probably represent the richest beds in fossil plants in Britain: there is a great variety of species, and the state of preservation is excellent,

(5) as in recent years, plant petrifications have been obtained.[1]

Although the coalfield is one of the best known in Britain, much work remains to be done, especially as, prior to 1925, almost all the plant records lack a definite horizon. Besides noting additional records, I have here brought together all the plants known from the area, at the same time indicating a number of necessary corrections. It has also been possible to make a suggestion as to the probable age of the Pennant Rock in the Northern portion of the coalfield, to confirm the reference of the New Rock and Vobster Series to the Blackband Group of the Staffordian Series, and of the upper beds of the so-called Millstone Grit to the Yorkian Series.

II. Description of Coalfield

The Bristol and Somerset Coalfield stretches about 26 miles from north to south and about 24 miles from east to west. The northern and southern limits are at Cromhall in Gloucestershire and Frome in Somersetshire, while the eastern and western limits are Bath and Nailsea.

Only about one-fifth of the approximately 150 square miles of Coal Measures are exposed at the surface, the remainder being covered unconformably by Jurassic and Triassic rocks.

[1] Crookall, R., 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, p. 161.

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The Kingswood anticline, occurring between Bristol and Warmley, divides the field into a northern and a southern area, while the latter is further divided by the Farmborough Fault, which runs roughly east to west a little to the north of Camerton and Timsbury. Excluding the outlying Nailsea basin (which has not been worked for many years), this gives three well-marked tracts of Coal Measures :—

(1) The Northern or Gloucestershire Area, which is itself conveniently subdivided into two districts, namely, that to the north of Bristol (where the Parkfield and Coalpitheath Pits work), and that around Bristol (Kingswood and Bedminster Pits).

(2) The Central or Pensford Area (Pensford and Bromley Pits).

(3) The Southern or Radstock Area (the most productive part of the coalfield).

The Coal Measures are divided by 2,500–3,000 feet of Pennant Rock (a coarse grey sandstone) into what are known locally as the Upper and Lower Divisions. The former includes two groups of coals, the Radstock Series (of 8 seams) and the Farrington Series (of usually 6 seams), and between these are 540–720 feet of strata near the middle of which are beds of red shale from 130 to 250 feet in thickness. The upper division is not present throughout the area. The Lower division underlies the entire coalfield and includes the strata between the Pennant Rock and the so-called Millstone Grit. It contains about 37 seams, of which 26 have proved productive. These seams include the New Rock Series (about 18 thin seams) and the Vobster Series (of 8 or more seams), the latter being the lowest coals in the district, but there is no definite line of separation between the two Series. The Coal Measures include a total of about 140 coal-seams, but most of these are too thin to be worked profitably, while in the Radstock area many of the upper seams are now worked out. The facts are summarised in the following table :—

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STRATA AND COAL SEAMS

Division and approximate thickness	Coal-seams	Number of seams	Development
'UPPER DIVISION' (2,200 feet)	Radstock Series	8	In Southern or Radstock Area only
	Red Shales (130–250 feet)		
	Farrington Series	Usually 6	(*a*) In Southern or Radstock Area (*b*) In Central or Pensford Area (*c*) In Northern or Gloucestershire Area
PENNANT ROCK (2,500–3,000 feet)	None ?	—	Practically throughout coalfield
'LOWER DIVISION' (2,800 feet)	New Rock Series	18 or more	Throughout coalfield
	Vobster Series	8 or more	
'MILLSTONE GRIT' (900–1,000 feet)	None workable	—	Throughout coalfield

In the following table are given the collieries working in the various areas, together with the series of coals worked. It shows at a glance the most productive portions of the coalfield.

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PITS WORKING AND SERIES WORKED

	NORTHERN AREA		CENTRAL AREA (around Pensford)	SOUTHERN AREA (around Radstock, South of Farmborough Fault)
	North of Bristol (Gloucestershire)	around Bristol (Kingswood and Bedminster)		
RADSTOCK[1] SERIES	—	—	—	Wellsway Pit ; Priston Pit ; Camerton Pit ; Dunkerton Pit
BOTH RADSTOCK AND FARRINGTON SERIES[1]	—	—	—	Braysdown Pit; Kilmersdon Pit
FARRINGTON SERIES[1]	Parkfield Pit, Pucklechurch ; Coalpitheath Colliery	— —	Broad Oak Colliery, Pensford ; Bromley Pit, near Pensford	Old Mills Pit ; Middle Pit ; Lower Writhlington Pit ; Foxcote Pit ; Ludlow's Pit ; Norton Hill Pit[3] ; Marsh Lane Pit[3] ; Bishop Sutton New Pit[3]
PENNANT ROCK	—	—	—	—
NEW ROCK AND VOBSTER SERIES[2]	—	South Liberty Colliery, Bedminster ; Deep and Speedwell Pits, Kingswood	—	Mells Pit ; New Rock Pit ; Newbury Pit ; Holcombe Pit ;

[1] Locally known as the ' Upper Division ' of the Coal Measures.
[2] Locally known as the ' Lower Division ' of the Coal Measures.
[3] These pits probably work the Farrington Series.

III. FAUNAL HORIZONS IN THE BRISTOL AND SOMERSET COALFIELD

It has been observed above that animal remains are not only comparatively rare in this coalfield, but that they are of somewhat restricted distribution. This especially applies to the ' Upper Division,' and correlation of the coalfield by this means, in the present state of our knowledge, cannot be satisfactorily attempted.

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In 1907 and 1911, Dr. H. Bolton[1] published lists of marine animals occurring locally, chiefly in the ' Lower Division ' at Ashton Vale Pit (now no longer working), and referred the beds to the Lower Coal Measures. The botanical data, however, which are available from the ' Lower Division ' throughout the coalfield, conclusively show the beds to belong to the Blackband Group of the Staffordian Series.

With regard to distribution, the case of *Leaia* may be mentioned. *Leaia leidyi* var. *williamsoni* was recorded by Dr. Bolton[2] from Coalpitheath Colliery. It is there quite common in the roof of the High Vein, embedded in patches in a distinct smooth type of shale, and is often accompanied by the small detached sporophylls known as *Lepidostrobus minor* (Goode). In view of the great value in correlation of the animal remains occurring in some coalfields, I have repeatedly carefully searched for this shell in the roof of the corresponding seam at the neighbouring colliery of Parkfield, but without success. I have never found this shell at Parkfield, either in the corresponding seam (there known as the Hollybush and Great Vein, combining to form a six-foot seam) or on the rubbish heap. The results obtained by Dr. Bolton (on faunal grounds) and by myself (on floral evidence) may be compared as follows :—

SERIES	FAUNAL HORIZON[3]	FLORAL HORIZON
' Coalpitheath and Parkfield Series ' (=Farrington Series)	True Lower Coal Measures	Newcastle Group of Staffordian Series
Pennant Rock ...	—	Staffordian Series
' Ashton and Bedminster Series of Bristol ' (=Lower Division)	True Lower Coal Measures	Blackband Group of Staffordian Series
' Vobster Series of Radstock ' (=Lower Division)	True Lower Coal Measures	Blackband Group of Staffordian Series

[1] Bolton, H., ' On a Marine Fauna in the Basement-beds of the Bristol Coalfield,' *Quart. Journ. Geol. Soc.*, vol. lxiii, 1907, p. 455, and ' Faunal Horizons in the Bristol Coalfield,' *Quart. Journ. Geol. Soc.*, vol. lxvii, 1911, p, 337.

[2] Bolton, H., 1911, *op. cit.*, p. 321.

[3] Bolton (*op. cit.*, 1911, p. 339) observes ' The accompanying synopsis . . . shows that the Ashton and Bedminster Series of Bristol, the Coalpitheath and Parkfield Series of the northern part of the coalfield, and the Vobster Series of Radstock which form the basement series of the Lower Coal-Measures, are all characterised by a fauna agreeing with the typical fauna of the Lower Coal Measures in the coalfields of the Midlands and of Lancashire and Yorkshire.'

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Dr. Bolton[1] observes, ' The marine fauna undergoes no marked change throughout—forms common in the Lower Coal Measures[2] ranging upwards, and not being replaced by new species. This lack of mutability will probably prevent the use of marine bands for zonal purposes. The continuity of life-forms in the Middle Coal Measures of Yorkshire is strikingly complete, less so in the Bristol Measures; but even here the long interval represented by the deposition of over 1,000 feet of Pennant Grit has not sufficed to prevent their recurrence at higher levels.'

While Coal Measure animals may, in some coalfields, prove of greater value than plant-remains in the correlation of individual seams, the data thus provided are often of local application only, and fossil plants as a rule give the safest data for correlating isolated coalfields, both in Europe and America.[3]

IV. Plant Records

(1) The first systematic investigation of the coalfield was published in 1888 by the late Dr. R. Kidston[4] who dealt mainly with the Radstock Series, the records from the other rocks being merely incidental. Many of the localities from which Kidston obtained his plants have been out of working for a number of years, or are now working different seams or even a different series of coals. The records, with certain necessary corrections, are given below.

RADSTOCK SERIES

FUNGI

Excipulites callipteridis (*Schimper*) Loc. Radstock.

PTERIDOSPERMEAE & FILICALES

Acitheca polymorpha (*Brongt.*) (recorded as *Pecopteris*) Locs. Radstock, Braysdown, Camerton.

Alethopteris aquilina (*Schloth.*) Locs. Radstock, Braysdown, Wellsway.

,, davreuxi (*Brongt.*) Locs. Radstock, Camerton.

,, grandini (*Brongt.*) Locs. Radstock, Braysdown, Wellsway, Upper Conygre.

,, lonchitica (*Schloth.*) (records require confirmation) Locs. Radstock, Braysdown, Middle Pit.

,, serli (*Brongt.*) Locs. Radstock, Braysdown, Wellsway, Upper Conygre, Lower Conygre, Dunkerton, Camerton, Welton Hill, Huish.

Alloiopteris radstockensis *Kidst.* (recorded as *Corynepteris erosa*) Loc. Camerton.

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[1] Bolton, H., *op. cit.*, 1911, p. 340.

[2] In this coalfield the term ' Lower Coal Measures ' can be used in a local sense only: true Lower Coal Measures (in the palaeobotanical sense) are absent.

[3] With regard to this aspect of the subject, see also Pringle, J., and R. Crookall, ' On Fossils from the Coal Measures of Kent,' ' Summary of Progress ' for 1927, part ii (*Mem. Geol. Surv.*), 1928, p. 84.

[4] Kidston, R., ' On the Fossil Flora of the Radstock Series of the Somerset and Bristol Coalfield (Upper Coal Measures)', part 1, *Proc. Roy. Soc. Edinb.*, vol. xxxiii, pt. ii, 1888, pp. 335–417.

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Asterotheca abbreviata (*Brongt.*) (recorded as *Pecopteris miltoni*: Mr. Hemingway suggests that *A. abbreviata* is distinct from *A. miltoni*, and the records are here provisionally kept separate) Locs. Radstock, Braysdown, Wellsway, Lower Conygre, Camerton, Welton Hill.

,, arborescens (*Schloth.*) (recorded as *Pecopteris*) Locs. Radstock, Braysdown, Wellsway, Upper Conygre, Kilmersdon, Camerton.

,, candolleana (*Brongt.*) (recorded as *Pecopteris*) Locs. Radstock, Braysdown, Wellsway, Middle Pit.

,, crenulata (*Brongt.*) (recorded as *Pecopteris*) Loc. Camerton.

,, cyathea (*Schloth.*) (recorded as *Pecopteris*) Locs. Radstock, Upper Conygre.

,, lamuriana (*Heer*) (recorded as *Pecopteris*) Locs. Radstock, Braysdown.

,, oreopteridia (*Schloth.*) (recorded as *Pecopteris*) Locs. Radstock, Wellsway, Braysdown, Upper Conygre, Camerton.

Crossotheca pinnatafida (*Gutb.*) (recorded as *Pecopteris*) Locs. Radstock, Upper Conygre, Camerton.

Dicksonites pluckeneti (*Schloth.*) Locs. Radstock, Upper Conygre, Kilmersdon, Welton Hill.

Diplotmema geniculatum (*Germ. & Kaul*) (recorded as *Sphenopteris*) Locs. Kilmersdon, Camerton.

Eupecopteris bucklandi (*Brongt.*) (recorded as *Pecopteris*) Loc. Camerton.

,, cisti (*Brongt.*) (recorded as *Pecopteris*) Loc. Dunkerton.

,, dentata (*Brongt.*) (recorded as *Dactylotheca plumosa*. Mr. Hemingway suggests that *E. dentata* is distinct from *D. plumosa*, and they are here provisionally kept apart). Locs. Radstock, Braysdown, Wellsway, Upper Conygre, Lower Conygre, Camerton.

,, pteroides (*Brongt.*) (recorded as *Pecopteris*) Loc. 'near Bath.'

,, villosa (*Brongt.*) (recorded as *Pecopteris*: type of species) Loc. Camerton.

Linopteris munsteri (*Eichw.*) (recorded as *Dictyopteris*) Loc. Camerton.

Macrosphenopteris lindsaeoides *Kidst.* Loc. Radstock.

Mariopteris (the species of this genus previously recorded were revised by Kidston in 1925, and these records only will be given).

Neuropteris fimbriata *Lesqx.* Locs. Wellsway, Upper Conygre, Camerton.

,, flexuosa *Sternb.* Locs. Radstock, Upper Conygre, Lower Conygre, Camerton.

,, macrophylla *Brongt.* Locs. Radstock, Braysdown, Wellsway Upper Conygre, Lower Conygre, Kilmersdon, Dunkerton.

,, obliqua (*Brongt.*) (recorded as *Alethopteris obliqua*—from Camerton—record should probably be suppressed).

,, ovata *Hoffm.* Locs. Radstock, Wellsway, Upper Conygre, Camerton.

,, rarinervis *Bunb.* Locs. Radstock, Wellsway, Upper Conygre, Lower Conygre, Camerton.

,, scheuchzeri *Hoffm.* Locs. Radstock, Braysdown, Wellsway, Upper Conygre, Lower Conygre, Camerton.

Odontopteris lindleyana (*L. & H.*) Locs. Radstock, Braysdown.

Pecopteris aspera *Brongt.* (Kidston's doubtful record of this species from Upper Conygre Pit should probably be suppressed).

,, pennaeformis *Brongt.* (Kidston's record of *P. pennaeformis* = *Senftenbergia ophiodermatica*, from Camerton should be suppressed: the species has not yet been recorded from Britain).

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Ptychocarpus unitus (*Brongt.*) (recorded as *Pecopteris*) Locs. Radstock, Braysdown, Wellsway, Upper Conygre, Lower Conygre, Kilmersdon, Camerton.

,, ,, forma emarginata *Goepp.* Locs. Radstock, Braysdown, Wellsway, Upper Conygre, Camerton.

Radstockia sphenopteroides (*Kidst.*) (recorded as *Schizostachys*) Loc. Radstock.

Sphenopteris alata *Brongt.* (recorded as *S. grandini*) Locs. Radstock, Braysdown, Lower Conygre, Kilmersdon.

,, cristata *Brongt.* (record from Camerton has been described as *Mariopteris plumosa*).

,, macilenta *L. & H.* Locs. Radstock, Braysdown, Camerton,

,, neuropteroides *Boulay* Locs. Radstock, Camerton, Withy. Clandown.

,, sewardi *Kidst.* (recorded as *S. tenuifolia*) Loc. Upper Conygre.

,, trifoliolata *Artis* (record from Deep Pit omitted from Kidston Memoir and should be suppressed).

,, woodwardi *Kidst.* Loc. Camerton.

Unatheca oblonga *Kidst.* (recorded as *Ptychocarpus oblongus*) Loc. Camerton.

PTERIDOSPERMEAE AND FILICALES INCERTAE SEDIS

Aphlebia crispa (*Gutb.*) (recorded as *Rhacophyllum*) Locs. Braysdown, Camerton.

,, filiciformis (*Gutb.*) (recorded as *Rhacophyllum*) Locs. Radstock, Camerton.

,, goldenbergi *Weiss* (recorded as *Rhacophyllum*) Loc. Radstock.

,, spinosa *Lesqx.* (recorded as *Rhacophyllum*) Loc. Radstock.

Caulopteris anglica *Kidst.* Locs. Radstock, Camerton.

,, peltigera (*Brongt.*) (recorded as *C. macrodiscus*) Locs. Radstock, Camerton.

,, primaeva *L. & H.* Locs. Radstock, Camerton.

,, sp. Locs. Radstock, Camerton.

Megaphyton elongatum *Kidst.* Loc. Radstock.

,, frondosum *Artis* Locs. Radstock, Camerton, Middle Pit.

Spiropteris sp. Loc. Braysdown.

LYCOPODIALES

Asolanus camptotaenia *Wood* (recorded as *Sigillaria monostigma*) Locs. Braysdown, Lower Writhlington.

Lepidodendron aculeatum *Sternb.* Locs. Radstock, Braysdown, Wellsway, Camerton.

,, lanceolatum *Lesqx.* Locs. Radstock, Braysdown, Upper Conygre, Camerton.

,, rhombicum (*Sternb.*) Loc. Upper Conygre.

,, wortheni *Lesqx.* Locs. Radstock, Braysdown, Wellsway, Camerton.

Lepidophloios sp. Locs. Radstock, Camerton.

Lepidophyllum brevifolium *Lesqx.* (recorded as *Lepidophyllum sp.*) Locs. Radstock, Braysdown.

,, majus *Brongt.* Locs. Radstock, Upper Conygre, Camerton.

Lepidostrobus ? spinosus *Kidst.* Loc. Braysdown.

,, sp. Loc. Radstock.

Lycopod macrospores. Loc. Radstock.

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Sigillaria alternans *Sternb.* Locs. Radstock, Braysdown.
,, cumulata *Weiss* (recorded as *S. tessellata*) Locs. Radstock, Braysdown, Camerton.
,, ,, forma nodosa *Bowman* Loc. Braysdown.
,, laevigata *Brongt.* Locs. Radstock, Braysdown.
,, major *L. & H.* Loc. Radstock.
,, mc'murtriei *Kidst.* Locs. Radstock, Braysdown.
,, notata *Brongt.* Loc. Dunkerton.
,, reniformis *Brongt.* Loc. Radstock.
,, ,, forma radstockensis *Kidst.* Loc. Radstock.
,, serli *Brongt.* Loc. Radstock.
Stigmaria anglica (*Sternb.*) Locs. Radstock, Camerton, Paulton.
,, ficoides (*Sternb.*) Locs. Radstock, Lower Conygre, Kilmersdon, Welton Hill.
,, ,, forma minor *Gein.* Loc. Braysdown.

EQUISETALES

Annularia sphenophylloides (*Zenk.*) Locs. Radstock, Braysdown, Upper Conygre, Lower Conygre, Kilmersdon, Camerton.
,, stellata (*Schloth.*) Locs. Radstock, Braysdown, Upper Conygre, Lower Conygre, Kilmersdon, Camerton, Paulton.
Asterophyllites equisetiformis (*Schloth.*) Locs. Radstock, Braysdown, Wellsway, Upper Conygre, Kilmersdon.
Calamites carinatus *Sternb.* (recorded as *C. ramosus*) Locs. Radstock, Camerton, Upper Conygre, Kilmersdon.
,, cisti *Brongt.* Locs. Radstock, Braysdown, Wellsway, Lower Writhlington, Camerton.
,, multiramis *Weiss* (*K. & J.*) (recorded as *C. cruciatus senarius*) Loc. Camerton.
,, suckowi *Brongt.* Locs. Radstock, Camerton.
,, undulatus *Sternb.* (recorded as *C. varians* var. *insignis*) Loc. Camerton.
,, sp. (recorded as *C. cannaeformis*) Locs. Camerton, Welton Hill.
Calamostachys tuberculata (*Sternb.*) (recorded as *Stachannularia*) Loc. Radstock.
Macrostachya infundibuliformis (*Brongt.*) Locs. Radstock, Kilmersdon.

SPHENOPHYLLALES

Sphenophyllum emarginatum *Brongt.* Locs. Radstock, Braysdown, Upper Conygre, Lower Conygre, Camerton, Paulton.

CORDAITALES

Cordaites angulosostriatus *Grand 'Eury* Locs. Radstock, Upper Conygre, Camerton.
Poacordaites microstachys (*Gold.*) Locs. Radstock, Braysdown.

SEMINA INCERTAE SEDIS

Carpolithus membranaceus *Goepp.* (recorded as *C. ovoideus*) Locs. Wellsway, Camerton.
,, sp. Loc. Upper Conygre.
Cordaicarpus gutbieri *Gein.* Loc. Radstock.
Holcospermum multistriatum (*Presl.*) (recorded as *Rhabdocarpus*) Loc. Radstock.
Samaropsis fluitans (*Dawson*) (recorded as *Cardiocarpus*—these records require confirmation) Loc. Upper Conygre.
Trigonocarpus ? dawesii *L. & H.* Loc. Camerton.
,, noeggerathi (*Sternb.*) Locs. Radstock, Upper Conygre, Camerton.

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INCERTAE SEDIS

Sporangia. Locs. Upper Conygre, ? Welton Hill.

FARRINGTON SERIES

PTERIDOSPERMEAE AND FILICALES

Alethopteris grandini (*Brongt.*) Loc. Old Mills.
,, lonchitica (*Schloth.*) (records require confirmation). Locs. Top Vein, Parkfield, Middle Pit.
,, serli (*Brongt.*). Locs. Old Mills, Farrington, Middle Pit.
Asterotheca arborescens (*Schloth.*) (recorded as *Pecopteris*) Locs. Parkfield, Old Mills.
,, oreopteridia (*Schloth.*) (recorded as *Pecopteris*) Locs. Parkfield, Farrington.
Dicksonites pluckeneti (*Schloth.*) Locs. Foxcote, Farrington.
cf. Diplotmema zeilleri *Stur* (recorded as *Sphenopteris sp.*) Loc. Old Mills.
Eupecopteris pteroides (*Brongt.*) (recorded as *Pecopteris*, but record should be suppressed) Loc. Parkfield.
Neuropteris flexuosa *Sternb.* Loc. Old Mills.
,, macrophylla *Brongt.* Locs. Top Vein, Parkfield, Old Mills, Farrington.
,, ovata *Hoffm.* Locs. Hollybush Vein, Parkfield, Old Mills.
,, rarinervis *Bunb.* Locs. Foxcote, Old Mills.
,, scheuchzeri *Hoffm.* Locs. Foxcote, Old Mills, Farrington, Middle Pit.
Ptychocarpus unitus (*Brongt.*) (recorded as *Pecopteris*). Locs. Old Mills, Farrington.
Sphenopteris macilenta *L. & H.* Loc. Old Mills.
,, neuropteroides *Boul.* Loc. Old Mills.
,, sp. Loc. Old Mills.
Aphlebia crispa (*Gutb.*) (recorded as *Rhacophyllum*) Locs. Parkfield, ? Old Mills.
,, goldenbergi *Weiss* (recorded as *Rhacophyllum*) Loc. Parkfield.
,, sp. (recorded as *Rhacophyllum*). Loc. Farrington.
Caulopteris peltigera (*Brongt.*) (recorded as *C. macrodiscus*) Loc. Coalpitheath.
,, sp. Loc. Old Mills.

LYCOPODIALES

Asolanus camptotaenia *Wood* (recorded as *Sigillaria monostigma*) Loc. Old Mills.
Lepidodendron wortheni *Lesqx.* Loc. Old Mills.
Lepidostrobus sp. Loc. Old Mills.
Sigillaria cumulata *Weiss* (recorded as *S. tessellata*) Loc. Foxcote.
,, elongata forma minor *Bgt.* Loc. Parkfield.
,, mc'murtriei *Kidst.* Loc. Farrington.
,, reniformis *Brongt.* Loc. Coalpitheath.
,, voltzi *Brongt.* Loc. Coalpitheath.
Stigmaria ficoides (*Sternb.*) Locs. Parkfield, Foxcote, Old Mills.

EQUISETALES

Annularia sphenophylloides (*Zenk.*) Loc. Old Mills.
,, stellata (*Schloth.*) Locs. Parkfield, Old Mills, Farrington.
Calamites carinatus *Sternb.* (recorded as *C. ramosus*) Loc. Parkfield.
,, suckowi *Brongt.* Loc. Farrington.

SPHENOPHYLLALES

Sphenophyllum emarginatum *Brongt.* Locs. Parkfield, Old Mills, Farrington.

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CORDAITALES

Cordaites angulosostriatus *Grand 'Eury* Locs. Foxcote, Old Mills.

SEMINA INCERTAE SEDIS

Carpolithus membranaceus *Goepp.* (recorded as *C. ovoideus*) Loc. Old Mills.
Samaropsis fluitans (*Dawson*) (recorded as *Cardiocarpus*—record doubtful). Loc. Old Mills.
Trigonocarpus noeggerathi (*Sternb.*). Loc. Old Mills.

PENNANT ROCK

LYCOPODIALES

Lepidostrobus sp. Loc. Downend.
Stigmaria ficoides (*Sternb.*). Loc. ?

EQUISETALES

Calamites schutzeiformis *K. & J.* forma waldenburgensis (recorded as *C. approximatus*) Locs. Crewshole, Downend, Fishponds.
,, suckowi *Brongt.* Loc. Crewshole.
,, sp. (recorded as *C. cannaeformis*) Loc. Crewshole.

NEW ROCK SERIES

PTERIDOSPERMEAE AND FILICALES

Asterotheca arborescens (*Schloth.*) (recorded from Golden Valley as *Pecopteris*—record should be suppressed).
,, abbreviata (*Brongt.*) (recorded as *Pecopteris miltoni*—provisionally referred to *A. abbreviata*). Locs. Top Vein, Warmley, Golden Valley.

LYCOPODIALES

Asolanus camptotaenia *Wood* (recorded as *Sigillaria monostigma*) Loc. Warmley.
Lepidophloios sp. (recorded as *Halonia*) Loc. Fishponds.
Lepidostrobus sp. Loc. Speedwell.
Sigillaria cumulata *Weiss* Loc. ? Kingswood.
,, elongata *Brongt.* (recorded as *S. rugosa*). Loc. Kingswood.
,, major *L. & H.* Loc. Little Toad Vein, ? Speedwell.
,, mammillaris *Brongt.* Loc. Warmley.
,, ,, forma abbreviata *Weiss* Loc. Great Toad Vein, Kingswood.
,, scutellata *Brongt.* Loc. Kingswood.
,, tenuis *Achepohl* (recorded as *S. schlotheimii*) Loc. Top Vein, Kingswood.
Stigmaria ficoides (*Sternb.*) Locs. Kingswood, Bedminster.

EQUISETALES

Calamites suckowi *Brongt.* Loc. Thoroughfare Seam, Kingswood.

CORDAITALES

Cordaites angulosostriatus *Grand 'Eury.* Loc. Deep Pit.
,, sp. Loc. Kingswood.

VOBSTER SERIES

PTERIDOSPERMEAE AND FILICALES

Asterotheca oreopteridia (*Schloth.*) (recorded as *Peceopteris* from Ashton—record should be deleted).

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LYCOPODIALES

Lepidodendron aculeatum *Sternb.* Loc. Edford.
,, rimosum *Sternb.* Loc. between Stone Rag and Main Seam, Edford.
Sigillaria mammillaris *Brongt.* Loc. Ashton.
,, rugosa *Brongt.* (recorded as *S. sillimanni*) Loc. Ashton.

EQUISETALES

Calamites undulatus *Sternb.* (recorded as *C. varians* var. *insignis*) Loc. Edford.
,, sp. (recorded as *C. cannaeformis*). Loc. Edford.

SPHENOPHYLLALES

Sphenophyllum emarginatum *Brongt.* Loc. Ashton.

(2) A number of subsequent records from the Bristol and Somerset Coalfield are due to Kidston. In *Summary of Progress* for 1913[1] he gave a list of plants from a boring at Hemington, Somerset, which, however, contained no species hitherto unrecorded from the coalfield. On stratigraphical grounds, the horizon from which they were obtained was regarded as probably the Farrington Series, but the species listed are common to both the Radstock and the Farrington Series. In 1921, Kidston[2] recorded the following species from a boring at Yate, Gloucestershire, the plants coming from the ' Lower Division ' of coals.

	Depths in feet
Corynepteris coralloides (*Gutbier*)	1,909
Linopteris *cf.* obliqua (*Bunbury*)	1,171
Lonchopteris bricei *Brongt.*	1,974
Mariopteris sp.	1,171
Neuropteris tenuifolia (*Schloth.*)	1,525, 1,711
,, sp.	1,525, 1,697 1,711, 1,719
Pecopteris (Dactylotheca ?) sp.	1,697
,, sp.	1,525,[3]1,562
,, striata *Gothan*[4]	1,711
,, sp.	1,804-1,810
Calamites cisti *Brongt.*	1,804-1,810
,, sp.	1,804-1,810
Annularia microphylla *Sauveur*	1,909
Asterophyllites equisetiformis (*Schloth.*)...	1,525
Palaeostachya sp.	1,973
Lepidostrobus lanceolatus (*L. & H.*)[5]	1,711
Sigillaria mammillaris *Brongt.*	1,510
Cordaites principalis (*Germar*)	1,525
,, sp.	1,711, 1,804, 1,810

[1] Kidston, R., ' Note on Fossil Plants met with in a Boring for Coal at Hemington, Somerset,' ' Summary of Progress ' for 1913, (*Mem. Geol. Surv.*), 1914, p. 101.

[2] Kidston, R., in Pringle, J., ' On a Boring for Coal, at Yate, Gloucestershire,' ' Summary of Progress ' for 1920 (*Mem. Geol. Surv.*), 1921, p. 95.

[3] Recorded as *S. cf artemisaefolioides* Crepin, but the plant appears to be absent from Britain.

[4] Specimen recorded as *S. obtusiloba* Brongt., but the British fossils referred to this species by Kidston were later recognised as distinct and referred to *S. striata.*

[5] Recorded as *Lepidophyllum lanceolatum.*

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In 1917, Kidston and Jongmans[1] mentioned the following additional species of *Calamites* from the coalfield.

Calamites schutzeiformis *K. & J.* forma typicus from Camerton.
,, ,, ,, ,, waldenburgensis *Kidst. pro sp.* from Radstock.
,, carinatus *Sternb.* from Farrington and Kingswood.
,, undulatus *Sternb.* from Deep Pit.

Kidston noted the following additions to the flora in his Memoir on Fossil Plants of the Carboniferous Rocks of Great Britain.[2]

Sphenopteris alata *Brongt.* Loc. Middle Pit.
,, pecopteroides *Kidst.* Loc. Kilmersdon.
Unatheca oblonga *Kidst.* Loc. Lower Conygre.
Eupecopteris dentata (*Brongt.*) (recorded as *Dactylotheca plumosa*, provisionally referred to *E. dentata*) Loc. Kilmersdon.
Dicksonites pluckeneti (*Schloth.*) Loc. Braysdown.
Asterotheca arborescens (*Schloth.*) Loc. Coalpitheath.
,, cyathea (*Schloth.*) Loc. Wellsway.
,, abbreviata (*Brongt.*) Loc. Farrington.
,, hemitelioides (*Brongt.*) Locs. Radstock, Kilmersdon, Upper Conygre, Camerton.
,, lepidorachis (*Brongt.*) Loc. Camerton.
,, daubreei (*Zeiller*) Locs. Radstock, Wellsway.
Ptychocarpus unitus (*Brongt.*) Loc. Norton Hill.
Eupecopteris bucklandi (*Brongt.*) Loc. Radstock.
,, cisti (*Brongt.*) Locs. Braysdown, Coalpitheath.
,, fletti *Kidst.* Locs. Radstock, Wellsway, Camerton.
,, camertonesis *Kidst.* Loc. Camerton.
Pecopteris armasi *Zeiller* Loc. Wellsway.
Mariopteris nervosa (*Brongt.*) Loc. Radstock, Deep Pit.
,, plumosa *Kidst.* Loc. Camerton.

(3) In 1910, D. G. Lillie[3] investigated the flora of Farrington Series of the northern area of the coalfield, his fossils being obtained from the spoil heaps, so that their horizons are unknown. We note the following records :—

PTERIDOSPERMEAE AND FILICALES

Acitheca polymorpha (*Brongt.*) (recorded as *Pecopteris*) Loc. Coalpitheath.
Alethopteris serli (*Brongt.*) Loc. Shortwood.
Asterotheca crenulata (*Brongt.*) (recorded as *Pecopteris*) Loc. Coalpitheath.
,, abbreviata (*Brongt.*) (recorded as *Pecopteris miltoni*—provisionally referred to *A. abbreviata*) Locs. Coalpitheath, Parkfield, Shortwood.
Eupecopteris dentata (*Brongt.*) (recorded as *Dactylotheca plumosa*—provisionally referred to *E. dentata*) Loc. Shortwood.
? Macrosphenopteris sp. Loc. Parkfield.

[1] Kidston, R., and, W. J. Jongmans, Monograph of Calamites of Western Europe, Vol. I of the *Flora of the Carboniferous of the Netherlands and Adjacent Regions*, by W. J. Jongmans, atlas, plates, 1915, text, 1917. Gravenhage.
[2] Kidston, R., 'Fossil Plants of the Carboniferous Rocks of Great Britain' (*Mem. Geol. Surv.*) Palaeontology, vol. ii, 1923-1925 (parts 1-6).
[3] Lillie, D. G., ' Notes on the Fossil Flora of the Bristol Coalfield,' *Geol. Mag.*, N.S., decade v, vol. vii, 1910, pp. 58-67.

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Mariopteris sp. (recorded as *M. muricata*—record requires confirmation) Loc. Coalpitheath.

Neuropteris flexuosa *Sternb.* Loc. Parkfield.

,, scheuchzeri *Hoffm.* Loc. Coalpitheath.

Sphenopteris neuropteroides *Boulay* Locs. Coalpitheath, Parkfield.

,, ovatifolia *Lillie* Locs. Coalpitheath, Shortwood.

Aphlebia crispa (*Gutb.*) (recorded as *Schizopteris lactuca*) Loc. Coalpitheath.

,, spinosa *Lesqx.* (recorded as *Rhacophyllum*) Loc. Parkfield.

LYCOPODIALES

Lepidodendron lanceolatum *Lesqx.* Locs. Coalpitheath, Shortwood.

,, sp. (recorded as cf. *L. glincanum*, a species which occurs very rarely in Lower Carboniferous rocks only) Loc. Parkfield.

CORDAITALES

Cordaites angulosostriatus *Grand 'Eury* Loc. Coalpitheath.

Lepidophyllum majus *Brongt.* Loc. Coalpitheath.

(4) The following list of plants, identified by J. Pringle, occurs in an account of a boring at Winterbourne, Gloucestershire.[1]

	Depths in feet
Alethopteris lonchitica (*Schloth.*)	2,220
Linopteris obliqua (*Bunb.*)	1,200, 1,343
Neuropteris heterophylla *Brongt.*	2,130, 2,220, 2,280
Asterotheca miltoni (*Artis*)[2]	1,200
Pecopteris sp.	1,200
Sphenopteris sp.[3]	1,200, 2,160
,, trifoliolata (*Artis*)	2,121, 2,131
Calamites sp.	1,200, 2,231
Asterophyllites equisetiformis (*Schloth.*)...	1,200, 1,258
,, sp.	1,200
Sphenophyllum cuneifolium (*Sternb.*)	1,809
Palaeostachya sp.	1,809
Lepidostrobus minus (*Goode*)[4]	1,090
Cordaites principalis (*Germar*)	1,200, 2,130
,, sp.	2,191

(5) In 1914, the late Dr. E. A. N. Arber[5] mentioned several species of seeds from the coalfield; while he later recorded[6] a few examples of *Lepidostrobus* :—

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[1] Cantrill, T. C., and Smith, B., 'On a Boring for Coal at Winterbourne, Gloucestershire,' 'Summary of Progress' for 1918 (*Mem. Geol. Surv.*), 1919, pp. 53-57.

[2] Recorded as *Pecopteris miltoni.*

[3] One specimen recorded as *S. cf. elegans* Brongt., but cannot belong to that species, which is a Lower Carboniferous form now known as *Diplotmema adiantoides* (Schl.).

[4] Recorded as *Lepidophyllum minus.*

[5] Arber, E. A. N., *Ann. of Botany*, 1914, vol. xxviii, pp. 96, 98, 101.

[6] Arber, E. A. N., *Journ. Linn. Soc.*, 1922, vol. xlvi, pp. 178, 180, 186.

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Samaropsis sp. (recorded as *S. fluitans*, but Kidston, *Proc. Roy. Soc. Edin.* vol. li, pt. iv, No. 27, p. 1031, disagreed with the specific determination) Loc. Camerton.

Holcospermum rugosum (*Arber*) (recorded as *Platyspermum*) Loc. Radstock.

Carpolithus sp. (recorded as *Radiospermum elongatum* n. sp., but *Radiospermum* is an unsatisfactory genus: the specimen will need to be re-examined) Locs. Radstock, Bishop Sutton.

,, ,, (recorded as *Radiospermum grande* n. sp.) Loc. Radstock.

Rhabdocarpus lillianus *Arber* Loc. Coalpitheath.

Lepidostrobus brevifolius *Lesqx.* Loc. Coalpitheath.

,, ? spinosus *Kidst.* Loc. Radstock.

,, lanceolatus (*L. & H.*) Loc. Radstock.

,, hastatus *Lesqx.* Loc. Coalpitheath.

(6) In 1925, the writer[1] published the results of an investigation which covered the whole coalfield. Special attention was paid to the northern area, the Central Area around Pensford and to the upper beds of the 'Millstone Grit.' Beyond the following notes and corrections, these records do not require repeating here.

PTERIDOSPERMEAE AND FILICALES

p. 149—*Pecopteris miltoni* is here provisionally recorded as *Asterotheca abbreviata*.

pp. 149, 151, 153, 154, 386—*Dactylotheca plumosa* is here provisionally referred to as *Eupecopteris dentata*.

pp. 149, 151, 153, 386—The records of Mariopteris require revising, and are here given as *Mariopteris sp.*

p. 149—The *Sphenopteris sp.* from Midsomer Norton is a new species awaiting description.

p. 151—*Alethopteris cf. integra*: this is *Pecopteris sp.*

pp. 155, 386—*Dictyopteris=Linopteris.*

p. 157—*Odontopteris conwayi=Margaritopteris conwayi.*

p. 385—*Sphenopteris ? sauveuri=Sphenopteris sp.*

p. 386—? *Oligocarpia brongniarti=Sphenopteris sp.*

LYCOPODIALES

pp. 150, 152—*Lepidophloios laricinus*: specific determination requires confirmation.

pp. 152, 387—*Lepidodendron loricatum=L. dichotomum* Zeiller.

SPHENOPHYLLALES

p. 387—*Sphenophyllum fasciculatum*: this specimen is probably a new species.

p. 387—*Sphenophyllum ? oblongifolium*; recorded as *Sphenophyllum sp.*

EQUISETALES

p. 154—*Stachannularia tuberculata=Calamostachys.*

SEMINA INCERTAE SEDIS

pp. 148, 153, 386—*Cyclopteris orbicularis*: specific determination probably incorrect: here recorded as *Cyclopteris sp.*

p. 150—*Schizospermum noeggerathi=Trigonocarpus.*

[1] Crookall, R., 'On the Fossil Flora of the Bristol and Somerset Coalfield,' 1925, *Geol. Mag.*, vol. lxii, pt. 1, pp. 145–180, pt. ii, pp. 385–410.

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p. 155—*Megalospermum inflatum*=*Carpolithus.*
p. 156—*Cordaicarpus areolatus*=*Carpolithus.*
p. 386—? *Radiospermum grande*=*Carpolithus sp.*
p. 387—*Radiospermum perpusillum*=*Carpolithus.*
p. 387—*Cordaicarpus ovoideus*=*C. membranaceus.*

PTERIDOSPERMEAE AND FILICALES INCERTAE SEDIS

p. 148—*Caulopteris cisti*=*C. peltigera.*

(7) There are a number of additional records to be made to the flora of the coalfield. Many of these specimens have been submitted to me for identification from time to time, others represent my own collecting.

RADSTOCK SERIES.—Mr. A. W. Coysh, B.Sc., collected the following plants from Clandown Pit, near Radstock, and the records are of value as this pit ceased working some time ago.

Sphenopteris macilenta *L. & H.*
Asterotheca abbreviata (*Brongt.*).
Eupecopteris camertonensis *Kidston.*
Eupecopteris sp.
Neuropteris scheuchzeri *Hoffm.*
Neuropteris flexuosa *Sternb.*
Mariopteris sp.
Sphenophyllum emarginatum *Brongt.*
Stigmaria ficoides (*Sternb.*).

FARRINGTON SERIES

Horizon : Middle Seam (Keele Group).
Locality : Norton Hill Pit, Midsomer Norton, near Radstock.
Lepidodendron aculeatum *Sternb.*
Horizon : ?
Locality : Broad Oak Colliery, Pensford.
Odontopteris britannica *Gutb.* (=Neuropteris obliqua (*Brongt.*)).

PENNANT ROCK (Staffordian Series)

Locality : Sandford (or Conygre) Quarry, Sandford, near Bristol.
Calamites suckowi *Brongt.*
Calamites sp.
Lepidodendron sp.
Stigmaria ficoides (*Sternb.*).
Locality : Staplehill, near Bristol.
Artisia transversa (*Artis*).
Artisia approximata (*Brongt.*).
Locality : Blue Pennant Quarry, Fishponds, Bristol.
Lepidodendron sp. (in Lyginodendroid condition).
Sigillaria sp.
Locality : Hanham Quarry, Bristol.
Calamites sp.
Lepidodendron sp. (in Lyginodendroid condition).
Sigillaria sp.

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Locality: Temple Cloud Quarry, Somerset.
Neuropteris sp.
Neuropteris scheuchzeri *Hoffm.*
Neuropteris rarinervis *Bunb.*
Calamites suckowi *Brongt.*
Calamites cf. undulatus *Sternb.*
Sphenophyllum saxifragaefolium (*Sternb.*)
Lepidodendron sp.
Sigillaria sp.

VOBSTER SERIES

Locality: Hanham Pit (now no longer working).
Cordaites principalis (*Germar*).

'MILLSTONE GRIT'

Locality: Wick Rocks, near Bristol. (Collected by Mr. A. W. Coysh).
Neuropteris obliqua (*Brongt.*)—common.
Renaultia chaerophylloides (*Brongt.*)—very rare.
Sphenophyllum cf. trichomatosum *Stur*—very rare.
Stigmaria ficoides (*Sternb.*)—very common.
Dorycordaites palmaeformis (*Goepp.*)—very rare.

Locality: Celestine Workings, Yate, near Bristol. (Collected by Dr. Stanley Smith).
Neuropteris schlehani *Stur.*

From the disturbed ground in the Great Western Railway Cutting at Cattybrook, near Pilning, Gloucestershire, Professor S. H. Reynolds and Dr. Stanley Smith collected a number of specimens which were identified by the writer as *Stigmaria ficoides* (Sternb.), *Sigillaria* sp., Lycopod megaspores, *Calamites undulatus* Sternb., *C. suckowi* Brongt., *Calamites sp.*, *Annularia? radiata* Brongt., and *Cordaites principalis* (Germar.)

LOWER CARBONIFEROUS (grit, etc., between Limestones D 1 and D 2—collected by Dr. Stanley Smith).

Locality: Wick Rocks, near Bristol.
Rachis of Fern or Pteridosperm.
Lepidodendron sp. (in Lyginodendroid condition).

Dr. Smith observes that these plant remains were accompanied by a fairly high Lower Carboniferous fauna. It is to be hoped that better preserved plants will be found in these beds.

We are now in a position to draw up the complete known flora of the coalfield: this is given below, the Pennant Rock being taken as the main line of division.

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Complete Flora of Coalfield

I. 'UPPER DIVISION' (RADSTOCK AND FARRINGTON SERIES)

	Radstock Series	Farrington Series		
		North	Central	South
FUNGI				
Excipulites callipteridis (*Schimp.*)	x	x	x	–
PTERIDOSPERMEAE AND FILICALES				
Acitheca polymorpha (*Brongt.*)	x	x	x	x
Alethopteris aquilina (*Schloth.*)	x	x	x	x
,, cf. costei *Zeiller* ...	–	x	–	–
,, davreuxi (*Brongt.*)	x	x	x	x
,, grandini (*Brongt.*)	x	x	–	x
,, ? lonchitica (*Schloth.*)	x	x	–	x
,, pontica Zeiller ...	–	x	–	–
,, serli (*Brongt.*) ...	x	x	x	x
,, cf. valida *Boulay*	–	–	x	–
Alloiopteris radstockensis *Kidst.*	x	–	–	–
,, sp.	–	x	–	–
Asterothca abbreviata (*Brongt.*)	x	x	x	x
,, arborescens (*Schloth.*)	x	x	x	x
,, candolleana (*Brongt.*)	x	–	x	–
,, crenulata (*Brongt.*) ...	x	x	x	x
,, cyathea (*Schloth.*) ...	x	–	–	x
,, daubreei (*Zeiller*) ...	x	–	–	–
,, hemitelioides (*Brongt.*)	x	–	–	–
,, lamuriana (*Heer*)	x	–	–	–
,, lepidorachis (*Brongt.*)	x	–	–	–
,, oreopteridia (*Schloth.*)	x	x	x	x
Corynepteris sternbergi (*Ett.*) ...	–	–	x	?
Crossotheca crépini *Zeiller* ...	–	x	–	–
,, pinnatafida (*Gutb.*) ...	x	x	–	–
,, sp.	–	–	–	x
Dicksonites pluckeneti (*Schloth.*)	x	x	–	x
Diplotmema geniculatum (*Germ. & Kaul.*)	x	–	–	–
,, cf. zeilleri *Stur* ...	–	–	–	x
,, sp.	–	–	–	x
Dolerophyllum sp.	–	–	x	x
Eupecopteris bucklandi (*Brongt.*)	x	x	x	x
,, camertonensis *Kidst.*	x	–	x	–
,, cisti (*Brongt.*) ...	x	x	–	–
,, dentata (*Brongt.*)	x	x	x	x
,, fletti *Kidst.* ...	x	–	–	–
,, pteroides (*Brongt.*)	x	–	–	–
,, villosa (*Brongt.*) ...	x	–	–	–
,, sp.	x	x	–	–
Linopteris munsteri (*Eichw.*) ...	x	–	–	–
,, obliqua (*Bunb.*) ...	–	–	–	x
Macrosphenopteris lindsaeoides *Kidst.*	x	–	–	–
? Macrosphenopteris sp.	–	x	–	–

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'Upper Division'—*continued*

	Radstock Series	Farrington Series		
		North	Central	South
Mariopteris nervosa (*Brongt.*) ...	x	–	–	–
,, plumosa *Kidst.* ...	x	–	–	–
,, sp.	x	x	x	x
Neuropteris fimbriata *Lesqx.* ...	x	x	x	x
,, flexuosa *Sternb.* ...	x	x	x	x
,, heterophylla *Brongt.*	–	–	x	?
,, macrophylla *Brongt.*	x	x	x	x
,, obliqua (*Brongt.*) ...	–	–	x	–
,, ovata *Hoffm.* ...	x	x	x	x
,, rarinervis *Bunb.* ...	x	x	x	x
,, scheuchzeri *Hoffm.*...	x	x	x	x
,, schlehani *Stur* ...	–	–	x	–
,, sp.	–	x	–	–
Odontopteris alpina (*Presl.*) ...	–	–	x	–
,, lindleyana (*L. & H.*)	x	–	x	x
,, sp.	–	–	x	–
Pecopteris armasi *Zeiller* ...	x	–	–	–
Ptychocarpus unitus (*Brongt.*) ...	x	x	x	x
Radstockia sphenopteroides (*Kidst.*)	x	x	–	–
,, sp.	–	x	–	?
Renaultia chaerophylloides (*Brongt.*)	-	x	x	–
,, sp.	–	–	x	–
Sphenopteris alata *Brongt.* ...	x	x	–	x
,, laurenti *Andrae* ...	–	–	x	–
,, macilenta *L. & H.*	x	–	x	x
,, neuropteroides *Boul.*	x	x	x	x
,, ovatifolia *Lillie* ...	–	x	–	?
,, pecopteroides *Kidst.*	x	x	–	–
,, sewardi *Kidst.* ...	x	–	–	–
,, woodwardi *Kidst.*	x	–	–	–
,, sp.	x	–	x	x
Unatheca oblonga *Kidst.* ...	x	–	–	x
DETACHED ? MICROSPORO-PHYLLS				
? Whittleseya sp.	–	–	–	x
PTERIDOSPERMEAE AND FILICALES INCERTAE SEDIS				
Aphlebia crispa (*Gutb.*)	x	x	x	x
,, filiciformis (*Gutb.*) ...	x	–	–	–
,, goldenbergi *Weiss.* ...	x	x	–	–
,, spinosa *Lesqx.* ...	x	x	–	–
,, sp.	–	x	x	x
Caulopteris anglica *Kidst.* ...	x	–	–	–
,, peltigera (*Brongt.*) ...	x	x	–	–
,, primaeva *L. & H.* ...	x	–	–	–
,, sp.	x	–	–	x
Cyclopteris sp.	x	x	x	x

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'Upper Division'—*continued*

	Radstock Series	Farrington Series		
		North	Central	South
Megaphyton elongatum *Kidst.* ...	x	–	–	–
,, frondosum *Artis*	x	–	–	–
,, sp.	–	?	–	–
Spiropteris sp.	x	–	x	–
LYCOPODIALES				
Asolanus camptotaenia *Wood*	x	x	–	x
Leipdodendron aculeatum *Sternb.*	x	x	x	x
,, dichotomum *Zeiller*	–	x	–	x
,, distans *Lesqx.* ...	–	–	x	–
,, cf. jaraczewski *Zeill.*	–	x	–	–
,, lanceolatum *Lesqx.*	x	x	x	x
,, obovatum *Sternb.*	–	x	x	–
,, rhombicum (*Sternb.*)	x	–	–	–
,, rimosum *Sternb.*	–	x	–	–
,, wortheni *Lesqx.*	x	x	x	x
,, sp.	–	x	x	x
Lepidophloios laricinus *Sternb.* ...	–	x	–	x
,, sp.	x	–	–	x
Lepidophyllum brevifolium *Lesqx.*	x	x	x	–
,, majus *Brongt.* ...	x	x	x	–
,, triangularis *Zeill.*	–	–	x	x
,, sp.	–	–	–	x
Lepidostrobus hastatus *Lesqx.* ...	–	x	–	–
,, lanceolatus (*L. & H.*)	x	x	x	x
,, minus (*Goode*) ...	x	x	x	x
,, ? spinosus *Kidst.*	x	–	–	–
,, sp.	x	–	x	x
Lycopod macrospores	x	x	–	x
Sigillaria alternans *Sternb.* ...	x	–	–	–
,, cumulata *Weiss* ...	x	–	x	x
,, deutschiana *Brongt.* ...	–	x	–	–
,, elongata *Brongt.* ...	–	x	–	–
,, ,, forma minor *Bt.*	–	x	–	–
,, cf. germanica *Weiss.* ...	–	–	x	–
,, kidstoni *Crookall*	–	–	x	–
,, laevigata *Brongt.* ...	x	–	–	–
,, major *L. & H.* ...	x	x	–	–
,, mammillaris *Brongt.*	–	x	–	–
,, mauricii *Grand'Eury* ...	–	–	x	–
,, mc'murtriei *Kidst.* ...	x	–	–	x
,, notata *Brongt.*	x	–	–	–
,, nortonensis *Crookall* ...	–	–	–	x
,, ovata *Sauveur*	?	–	x	x
,, principis *Weiss*... ...	–	–	–	x
,, reniformis *Brongt.* ...	x	x	–	–

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'Upper Division'—*continued*

	Radstock Series	Farrington Series		
		North	Central	South
Sigillaria rugosa *Brongt.*	–	x	–	–
,, serli *Brongt.*	x	–	–	–
,, transversalis *Brongt.* forma sparsifolia *Boul.*	–	–	x	–
,, voltzi *Brongt.*	–	x	–	–
,, sp.	x	–	–	x
Sigillariophyllum bicarinatum (*L. & H.*)	x	x	x	x
Sigillariostrobus sp.	x	–	–	–
Stigmaria anglica (*Sternb.*) ...	x	–	–	–
,, ficoides (*Sternb.*) ...	x	x	x	x
,, ,, forma minor *Gein.* ...	x	–	–	–
,, minuta *Goepp.* pro var.	–	x	–	–
EQUISETALES				
Annularia radiata *Brongt.* ...	–	x	x	–
,, sphenophylloides (*Zenk.*)	x	x	x	x
,, stellata (*Schloth.*) ...	x	x	x	x
Asterophyllites equisetiformis (*Schloth.*)	x	x	x	x
,, longifolius (*Sternb.*)	–	x	–	–
Calamites carinatus *Sternb.* ...	x	x	x	x
,, cisti *Brongt.*	x	x	–	–
,, multiramis *Weiss* (*K. & J.*)	x	–	–	–
,, schutzeiformis *K. & J.* forma typicus ...	x	–	–	–
,, forma waldenburgensis *Kidst.* pro. sp. ...	x	–	–	–
,, suckowi *Brongt.* ...	x	x	x	x
,, undulatus *Sternb.*	x	–	–	–
,, sp.	x	x	x	x
Macrostachya infundibuliformis (*Brongt.*)	x	?	–	–
Calamostachys tuberculata (*Sternb.*)	x	–	x	–
SPHENOPHYLLALES				
Sphenophyllum cuneifolium (*Sternb.*)	–	x	x	–
,, emarginatum *Brongt.*	x	x	x	x
,, cf. fasciculatum *Lesqx.* ...	–	–	x	–
,, majus *Bronn* ...	–	–	?	x
,, saxifragaefolium (*Sternb.*) ...	–	–	x	–
,, sp.	–	x	x	x

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'Upper Division'—*continued*

	Radstock Series	Farrington Series		
		North	Central	South
CORDAITALES				
Cordaites angulosostriatus *Grand 'Eury*	x	x	x	x
,, borassifolius (*Sternb.*)	–	–	x	–
,, principalis (*Germar*) ...	–	–	–	?
,, sp.	x	x	x	x
Poacordaites microstachys (*Gold.*)	x	–	x	–
SEMINA INCERTAE SEDIS				
Carpolithus membranaceus *Goepp.*	x	–	x	x
,, perpusillus *Lesqx.* ...	–	–	x	x
,, sp.	x	–	?	x
Cordaicarpus gutbieri *Gein.* ...	x	–	–	–
Holcospermum mammillatum *Lesqx.*	–	–	x	–
,, multistriatum (*Presl.*)	x	–	–	–
,, rugosum (*Arber*)	x	–	–	–
Rhabdocarpus lillianus *Arber* ...	–	x	–	–
Samaropsis cf. fluitans (*Dawson*)	x	–	–	x
,, sp.	–	–	x	x
Trigonocarpus dawesii *L. & H.* ...	x	–	–	–
,, noeggerathi (*Sternb.*)	x	x	–	x
,, parkinsoni *Brongt.*	–	–	x	x
,, sp.	–	x	–	–
INCERTAE SEDIS				
Pinnularia capillacea *L. & H.* ...	x	x	–	x
,, columnaris (*Artis*) ...	–	–	x	x
Sporangia	x	–	–	–

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II. PENNANT ROCK, 'LOWER DIVISION' AND 'MILLSTONE GRIT'

	Pennant Rock	'Lower Division'		'Millstone Grit'
		New Rock Series	Vobster Series	
PTERIDOSPERMEAE AND FILICALES				
Alethopteris decurrens (*Artis*)	–	–	x	–
,, ? lonchitica (*Schl.*)	–	x	–	–
Asterotheca abbreviata (*Brongt.*)	x	x	–	–
,, arborescens (*Schl.*)...	–	x	–	–
Corynepteris coralloides (*Gutb.*)...	–	x	–	–
,, sternbergi (*Ett.*) ...	–	x	–	–
Crossotheca sp.	–	x	–	–
Desmopteris longifolia (*Stb.*) *Stur*	–	x	–	–
Diplotmema furcatum (*Brongt.*)	–	x	–	–
Dolerophyllum sp.	–	x	?	–
Eupecopteris dentata (*Brongt.*) ...	–	x	–	–
,, volkmanni (*Sauv.*)	–	x	–	–
Linopteris munsteri (*Eichw.*) ...	–	x	–	–
,, obliqua (*Bunb.*) ...	–	x	–	–
Lonchopteris bricei *Brongt.* ...	–	x	–	–
Margaritopteris conwayi (*L. & H.*)	–	–	–	x
Mariopteris nervosa (*Brongt.*) ...	–	x	–	–
,, sp.	–	x	x	–
Neuropteris heterophylla *Brongt.*	–	x	x	–
,, macrophylla *Brongt.*	–	x	–	–
,, obliqua *Brongt.* ...	–	x	–	x
,, pseudogigantea *Pot.*	–	x	?	–
,, rarinervis *Bunb.* ...	x	x	–	–
,, cf. raymondi *Zeill.* ...	–	x	–	–
,, scheuchzeri *Hoffm.*...	x	x	–	–
,, schlehani *Stur* ...	–	–	–	x
,, tenuifolia (*Schloth.*)	–	x	–	–
,, sp.	x	x	x	–
Pecopteris sp.	–	x	–	–
Renaultia chaerophylloides (*Bt.*)	–	–	–	x
Rhodea sp.	–	x	–	–
Sphenopteris dilatata *L. & H.* ...	–	x	–	–
,, laurenti *Andrae* ...	–	x	–	–
,, neuropteroides *Boul.*	–	x	–	–
,, striata *Gothan* ...	–	x	–	–
,, tenuissima *Presl.* ...	–	x	–	–
,, sp.	–	x	–	x
Unatheca oblonga *Kidst.* ...	–	x	–	–
Cyclopteris sp.	–	–	x	–
Spiropteris sp.	–	x	x	–
LYCOPODIALES				
Asolanus camptotaenia *Wood* ...	–	x	–	–
Lepidodendron aculeatum *Sternb.*	–	x	x	–
,, distans *Lesqx.* ...	–	–	–	x
,, lanceolatum *Lesqx.*	–	x	–	–
,, obovatum *Sternb.*	–	x	x	–
,, ophiurus *Brongt.*	–	x	–	–

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'Lower Division'—*continued*

	Pennant Rock	'Lower Division'		'Millstone Grit'
		New Rock Series	Vobster Series	
Lepidodendron rimosum *Sternb.*	–	–	x	–
,, simile *Kidst.* ...	–	x	–	–
,, wortheni *Lesqx.*	–	x	–	–
,, sp.	x	x	x	–
Lepidophloios laricinus *Sternb.*	–	–	–	?
,, sp.	–	x	–	–
Lepidophyllum majus *Brongt.*	–	x	–	–
,, morissianum *Lesqx.*	–	x	–	–
,, triangularis *Zeiller*	–	x	–	–
,, sp.	–	x	–	x
Lepidostrobus incertus *Lesqx.* ...	–	x	–	–
,, lanceolatus (*L. & H.*)	–	x	–	x
,, minus (*Goode*) ...	–	x	–	–
,, radians *Schimper*	–	x	–	–
,, sp.	x	x	x	x
Lycopod macrospores	–	x	x	–
Sigillaria cordigera *Zeiller* ...	–	x	–	–
,, cumulata *Weiss* ...	–	?	–	–
,, elongata *Brongt.* ...	–	x	–	–
,, major *L. & H.* ...	x	x	–	–
,, mammillaris *Brongt.* ...	–	x	x	–
,, ,, forma abbreviata *Weiss*	–	x	–	–
,, ovata *Sauveur*	–	x	–	–
,, rugosa *Brongt.* ...	–	x	x	–
,, sauli *Brongt.*	–	x	–	–
,, scutellata *Brongt.* ...	–	x	–	–
,, tenuis *Achep.* ...	–	x	–	–
,, tessellata *Brongt.* ...	–	x	–	–
,, sp.	x	–	x	–
Sigillariophyllum bicarinatum (*L. & H.*)	–	x	x	x
Stigmaria ficoides (*Sternb.*) ...	x	x	x	x
,, minuta *Goepp.* pro var.	–	x	–	–
Bark of unknown Lycopod ...	–	x	–	–
EQUISETALES				
Annularia microphylla *Sauveur*	–	x	–	–
,, radiata *Brongt.* ...	–	x	–	–
,, sphenophylloides (*Zenk.*)	–	x	–	–
,, sp.	–	x	x	–
Asterophyllites charaeformis (*Sternb.*)	–	x	–	–
,, equisetiformis (*Schl.*)	–	x	–	–
,, grandis (*Sternb.*)	–	x	–	–

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'Lower Division'—*continued*

	Pennant Rock	'Lower Division'		'Millstone Grit'
		New Rock Series	Vobster Series	
Calamites carinatus *Sternb.* ...	–	x	–	–
,, cisti *Brongt.*	–	x	–	–
,, schützeiformis *K. & J.* forma waldenburgensis *Kidst.* pro sp.	x	–	–	–
,, suckowi *Brongt.* ...	x	x	x	–
,, undulatus *Sternb.* ...	?	x	x	x
,, sp.	x	x	x	x
Palaeostachya pedunculata *Will.*	–	x	–	–
,, sp.	–	x	–	–
SPHENOPHYLLALES				
Sphenophyllum cuneifolium (*Sternb.*)	x	x	x	–
,, emarginatum *Brongt.*	–	x	x	–
,, myriophyllum *Crépin*	–	x	–	–
,, saxifragaefolium (*Sternb.*)	–	x	–	–
,, trichomatosum *Stur*	–	x	–	x
CORDAITALES				
Astisia approximata (*Brongt.*)	x	x	–	–
,, transversa (*Artis*) ...	x	x	x	–
Cordaites angulosostriatus *Grand 'Eury*	–	x	–	–
,, borassifolius (*Sternb.*)	–	x	–	–
,, principalis (*Germar*) ...	–	x	x	–
,, sp.	–	x	x	–
Dorycordaites palmaeformis (*Goepp.*)	–	–	x	x
SEMINA INCERTAE SEDIS				
Carpolithus inflatus (*Lesqx.*) ...	–	x	–	–
,, membranaceus *Goepp.*	–	x	–	–
,, areolatus *Boulay*	–	x	–	–
,, sp.	–	x	–	–
Cordaicarpus cordai (*Gein.*) ...	–	x	–	–
Holcospermum sp.	–	x	–	–
Samaropsis sp.	–	x	–	–
Trigonocarpus sp.	–	x	–	–
INCERTAE SEDIS				
Pinnularia capillacea (*L. & H.*)	–	x	x	–
,, columnaris (*Artis*) ...	–	x	–	–

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V. General Observations

A glance at the tables given above will suffice to show that the Radstock Series is by far the most prolific in plant remains, and it constitutes one of the richest beds in the British Coal Measures. It is closely followed, in this respect, by the Farrington Series, especially that section which occurs in the Southern Area where the Radstock Series is also developed. The Farrington Series of the Northern and Central Area is less rich. In the Pennant Rock, as is to be expected from the nature of the sediments, plants are extremely scarce. The ' Lower Division ' contains few plants and, although the New Rock Series has provided a fair number of species, these are all of rare occurrence. From the upper beds of the ' Millstone Grit ' a comparatively few species (of Yorkian) plants have been recorded, but some of these are very common.

THE RADSTOCK SERIES

The flora of the Radstock Series indicates that these beds represent a transition between the Stephanian and Westphalian, with affinities towards the latter rather than towards the former.

THE FARRINGTON SERIES

In 1888, Kidston[1] observed that, ' Palaeontologically, the Farrington Series cannot be separated from the Radstock Series, of which, in fact, they seem to form a part.' Lillie[2] investigated the flora of the Farrington Series of the Northern or Gloucestershire Area, and referred it to the Upper Coal Measures (Radstockian Series). Prior to my work published in 1925,[3] the Farrington Series of the Central or Pensford Area had not been investigated. Until then the Farrington Series throughout the coalfield had been regarded as belonging to the Upper Coal Measures. The writer, however, showed[4] that the beds were of slightly different age in the different areas : Farrington Series of

Northern (Gloucestershire) Area = Newcastle Group of Staffordian Series,

Central (Pensford) Area = Newcastle Group of Staffordian Series,

Southern (Radstock) Area = Keele Group of Staffordian Series.

The Newcastle-under-Lyme Group represents the highest group of the Staffordian Series, while the Keele Group is the lower group of the Radstockian Series. It should here be pointed out that, on account of the reference of the Farrington Series of the Southern

[1] Kidston, R., 1888, *op. cit.*, p. 410.
[2] Lillie, D. G., 1910, *op. cit.*, p. 67.
[3] Crookall, R., 1925, *loc. cit.*
[4] Crookall, R., 1925, *op. cit.*, pp. 395, 398, 400.

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Area to the Keele Group, Kidston's division (given below) of the Radstockian Series into the three following groups requires revision :

RADSTOCKIAN SERIES { Radstock Group / Farrington Group / Keele Group

THE PENNANT ROCK

As has been observed above, the Pennant Rock is extremely barren of fossils. This is no doubt due to the porosity of the rocks which, readily admitting air and water, resulted in the almost complete decay of the enclosed vegetable matter. Moulds and casts are consequently the only common fossils. The coarseness of the rocks also militates against anything like excellence of preservation. The Pennant Rock may in part represent the Etruria Marl Group (which is also very barren of fossil plants). If this were so, in the Bristol district we should have a complete succession of the Staffordian Rocks.

Northern (Gloucestershire) Area	Group
Farrington Series	Newcastle-under-Lyme Group
Pennant Rock	? Etruria Marl Group
New Rock and Vobster Series	Blackband Group

A comparison with the Kent Coalfield lends support to this suggestion. At the Tower Brickworks Boring the beds between 1,768 and 1,980 feet were provisionally referred by Kidston[1] to the Etruria Marl Group, while at Waldershare the Newcastle-under-Lyme Group is at 1,845 feet.

THE NEW ROCK AND VOBSTER SERIES

The New Rock and Vobster Series were referred by Kidston[2] to the Transition (= Staffordian Series), and were shown by the writer[3] to belong to the Blackband Group of that Series. An analysis of the plant remains obtained by the Geological Survey[4] from borings in these rocks in the Northern Area confirms this conclusion. This is given below.

[1] Kidston, R., 'Summary of Progress for 1918' (*Mem. Geol. Surv.*), 1919, p. 49.

[2] Kidston, R., 'On the Fossil Flora of the South Wales Coalfield, and the Relationship of its Strata to the Somerset and Bristol Coalfield' *Trans. Roy. Soc. Edinb.*, vol. xxxvii, pt. iii, no. 26, pp. 557-558.

[3] Crookall, R., 1925, *op. cit.*, p. 403.

[4] Cantrill, T. C., and B. Smith, 1919, *op. cit.*, p. 53, and Pringle, J., 1921, *op. cit.*, p. 92.

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ANALYSIS OF ZONAL SPECIES

Species recorded	General Distribution in Coal Measures		
	Radstockian	Staffordian	Yorkian
PTERIDOSPERMEAE AND FILICALES			
Alethopteris lonchitica (*Schloth.*)	? absent	very rare	very common
Asterotheca miltoni (*Artis*) ...	? absent	? very rare	very common
Corynepteris coralloides (*Gutb.*) ...	absent	very rare	fairly common
Linopteris obliqua (*Bunb.*) ...	absent	fairly rare	fairly common
Lonchopteris bricei *Brongt.* ...	absent	absent	fairly rare
Neuropteris heterophylla *Brongt.*	very rare	very rare	very common
,, tenuifolia *Schloth.* ...	absent	very rare	very common
Sphenopteris striata *Gothan* ...	absent	very rare	fairly common
,, ? trifoliolata (*Artis*)	absent	very rare	fairly common
EQUISETALES			
Calamites cisti *Brongt.*	very rare	vary rare	fairly common
Annularia microphylla *Sauveur* ...	absent	very rare	vary rare
SPHENOPHYLLALES			
Sphenophyllum cuneifolium (*Sternb.*)	absent	very rare	fairly common
LYCOPODIALES			
Sigillaria mammillaris *Brongt.* ...	absent	very rare	very common
CORDAITALES			
Cordaites principalis (*Germar*) ...	absent	fairly rare	very common

With the exception of *Linopteris obliqua, Lonchopteris bricei, Neuropteris tenuifolia, Sphenopteris striata, Calamites cisti,* and *Annularia microphylla,* all the above named plants have been recorded by the writer[1] from the New Rock and Vobster Series of this coalfield, where, however, they are of rare occurrence. They have all been recorded previously from the Staffordian Series (except *Annularia microphylla*) and are commoner in the Yorkian Series. There is a marked absence of Radstockian forms, but, while Yorkian species form the bulk of the flora, the typical rich Yorkian assemblage is not recognised. Many common Yorkian species of *Sigillaria, Sphenopteris, Neuropteris,* etc., are unrecorded, and those

[1] Crookall, R., *op. cit.,* 1925, p. 401.

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Yorkian plants which are present are all rare. This entirely confirms the previous reference of the beds to the lowest group of the Staffordian Series—the Blackband Group.

THE UPPER BEDS OF THE 'MILLSTONE GRIT'

Prior to 1925[1] there were no satisfactory records of plants from the 'Millstone Grit' of the Bristol and Somerset Coalfield. On the basis of the fossil flora obtained, however, it was possible to provisionally refer these beds to the Yorkian Series, an horizon which had hitherto been unrecognised in the coalfield. The above additional records[2] from these beds put the matter beyond doubt. All the plants listed, with the exception of *Stigmaria ficoides*, which has no specific or stratigraphical value, are typical of the Yorkian Series. No Radstockian species has been found in these rocks, while, though the total number of species occurring is comparatively small, several of the Yorkian plants are extremely common. The upper portion of the Millstone Grit to the north of Bristol must be referred to the Yorkian Series.

VI. CONCLUSIONS

The percentages of zonal plants occurring in each Series of the coalfield is given below :—

	Radstockian Species	Yorkian Species
Radstock Series	60	14
Farrington Series	42	28
New Rock and Vobster Series	18	56
Upper beds of 'Millstone Grit'	0	72

It will be seen that 70–75 per cent. of the species is diagnostic, the remainder being composed of non-zonal forms. There is a constant decrease in Radstockian and increase in Yorkian plants as the rocks are descended. These percentages, however, do not give an even approximately true indication of the stratigraphical value of the floras, as the frequency of the individual species is not taken into account. In the Radstock Series, for instance, probably 99 per cent. of the fossils are represented by examples of species of *Pecopteris*, together with *Alethopteris serli* and *Cordaites angulosostriatus*, while the Yorkian plants, though numbering 14 per cent. of the species-flora are invariably very rare, and most of the records are represented by a single specimen.

[1] Crookall, R., *op. cit.*, 1925, p. 403.
[2] See p. 72.

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The results obtained are summarised in Tables I and II, given below, as well as on Figs. 1 and 2, while Table III shows a comparison of the coalfield with neighbouring areas.

THE BRISTOL AND SOMERSET COALFIELD

TABLE I

	NORTHERN AREA		CENTRAL AREA (Pensford and Bromley)	SOUTHERN AREA (Around Radstock S. of Farmborough Fault)
	North of Bristol	Around Bristol (Kingswood)		
RADSTOCK SERIES	absent	absent	absent	present—Radstock Group of the Radstockian Series
FARRINGTON SERIES	present—Newcastle Group of the Staffordian Series	absent	present—Newcastle Group of Staffordian Series	present—Keele Group of the Radstockian Series
PENNANT ROCK	present—Staffordian Series	present—Staffordian Series	present—(presumably) Staffordian Series	present—(presumably) Staffordian Series
NEW ROCK AND VOBSTER SERIES	present—Blackband Group of the Staffordian Series	present—Blackband Group of the Staffordian Series	(presumably) present—(presumably) Blackband Group of the Staffordian Series	present—Blackband Group of the Staffordian Series
(upper) 'MILLSTONE GRIT'	present—Yorkian Series	present—(presumably) Yorkian Series	(presumably) present—(presumably) Yorkian Series	present—(presumably) Yorkian Series
(lower)	Lower Carboniferous (Vaughan)	Lower Carboniferous (Vaughan)	Lower Carboniferous (Vaughan)	Lower Carboniferous (Vaughan)

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TABLE II

SERIES	GROUP	NORTHERN OR GLOUCESTER-SHIRE AREA	CENTRAL OR PENSFORD AREA	SOUTHERN OR RADSTOCK AREA
RADSTOCKIAN SERIES	Radstock Group	absent	absent	Radstock Series
	Keele Group	absent	absent	Farrington Series
STAFFORDIAN SERIES	Newcastle-under-Lyme Group	Farrington Series	Farrington Series	? absent
	? Etruria Marl Group	Pennant Rock	Pennant Rock	Pennant Rock
	Blackband Group	New Rock and Vobster Series[1]	(presumably) New Rock and Vobster Series	New Rock and Vobster Series
YORKIAN SERIES	—	Upper Beds of 'Millstone Grit'	(presumably) Upper Beds of 'Millstone Grit'	(presumably) Upper Beds of 'Millstone Grit'
LANARKIAN SERIES	—	absent	absent	absent
LOWER CARBONI-FEROUS	—	Lower Beds of 'Millstone Grit' (Vaughan)		

[1] In the Bristol district proper (*i.e.*, at Hanham, South Liberty Colliery, and at Deep and Speedwell Pits) the New Rock and Vobster Series are the highest coals worked. Hanham pit is now closed.

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TABLE III

Series	Group	Bristol and Somerset Coalfield	Kent Coalfield	Forest of Dean Coalfield	South Wales Coalfield
RADSTOCKIAN	Radstock	present	absent	absent	?
	Keele	present	present	present	present
STAFFORDIAN	Newcastle	present	present	present	present
	Etruria Marl	? present	present	absent ?	present
	Blackband	present	? present	absent	present
YORKIAN	—	present	present	absent	present
LANARKIAN	—	absent	absent	absent	absent ?

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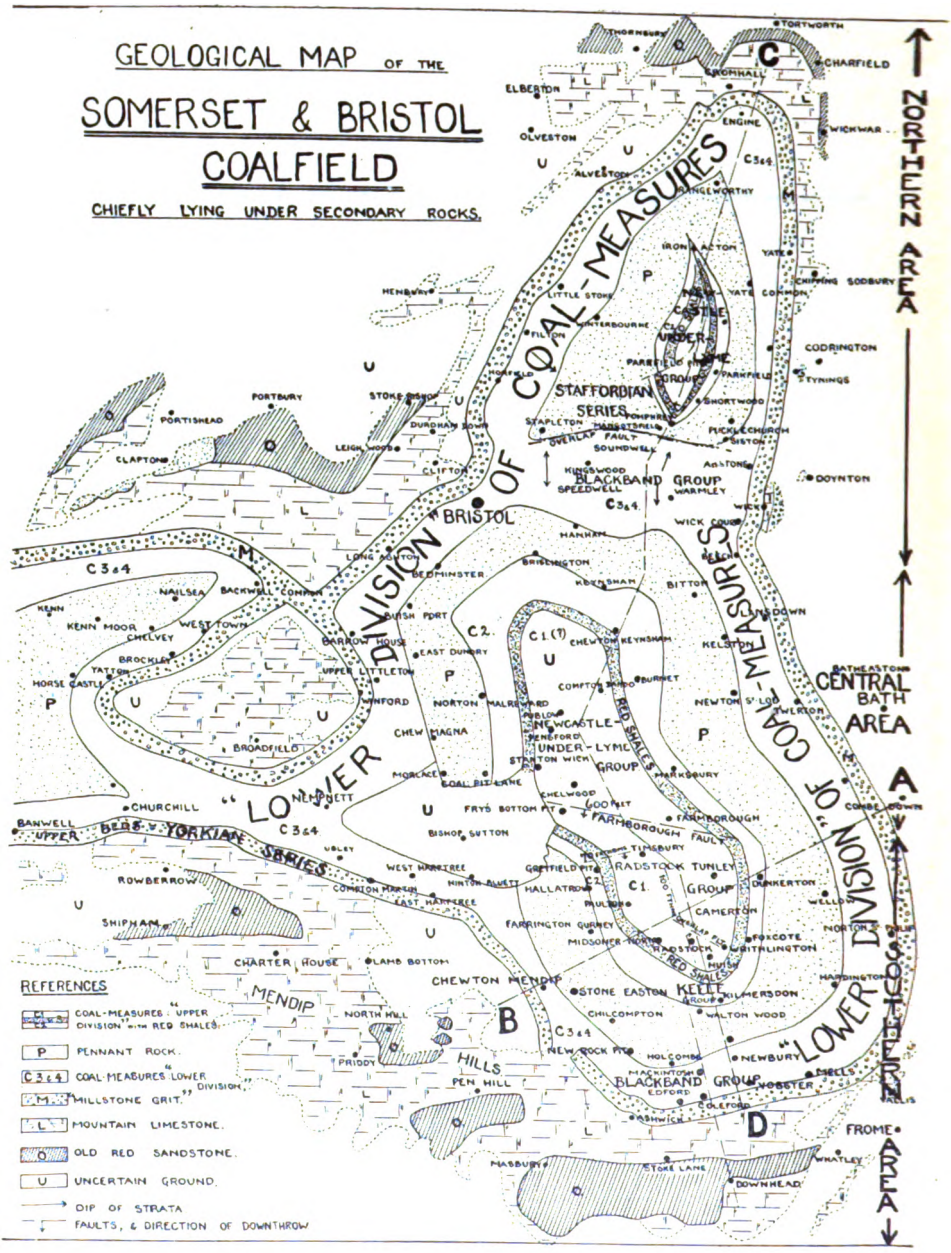

FIG. 1.—*Geological Map of the Bristol and Somerset Coalfield* showing geographical and palaeobotanical divisions (based on map published by J. McMurtrie, *Trans. Inst. Min. Eng.*, vol. xx, 1901, p. 334). Scale: 1·7 miles to 1 inch.

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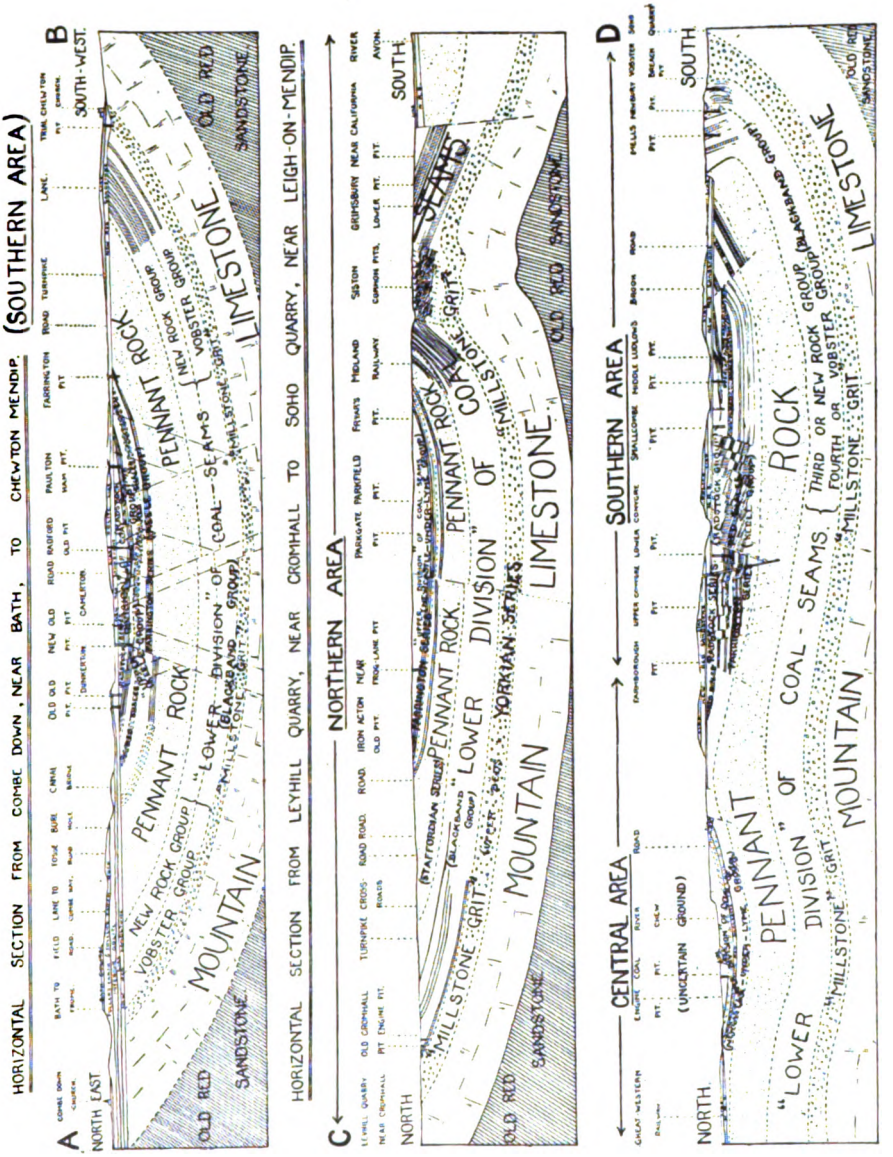

FIG. 2.—*Horizontal Sections from Combe Down, near Bath, to Chewton Mendip and Leyhill Quarry, near Cromhall to Soho Quarry, near Leigh-on-Mendip.*

showing geographical and palaeobotanical divisions

(based on section published by J. McMurtrie, *Trans. Inst. Min. Eng.*, vol. xx, 1901, p. 334). Horizontal Scale: ·4 mile to 1 inch. Vertical Scale: 2,000 feet to 1 inch.

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VI.—On the Fossil Xiphosura from the South Wales Coalfield with a note on the myriapod *Euphoberia*.

By Emily Dix, M.Sc., and John Pringle, F.G.S.

Text-figures 1 to 16

Introduction

Fossil remains of Xiphosura are rare in the Coal Measures, and few specimens have hitherto been recorded from the rocks of the South Wales Coalfield. A number of examples of the genera *Belinurus*, *Prestwichianella* and *Euproops*, however, have been collected by the writers of this paper; some of the specimens are exhibited in the collections of the Museum of Practical Geology, London, while, in addition to those preserved at the University College, Swansea, others from the David Davies collection in the National Museum of Wales, Cardiff, and in the University College, Cardiff, have been lent to us by Dr. F. J. North and Prof. A. H. Cox, for the purpose of description and comparison.

The fossil Xiphosura at present known from the South Wales Coalfield are, with the exception of one specimen, preserved as impressions. They usually occur in well-laminated shale with other arthropods and plants, but occasionally fresh-water shells are also found associated with them. In all cases only the dorsal surface of the animal is preserved.

In some other coalfields, *e.g.*, Nottinghamshire, Derbyshire and Shropshire, the remains of Xiphosura appear to be more numerous, and are usually preserved in ironstone nodules. In the course of our studies, we have been able to examine a number of well-preserved specimens from English localities, and to use them for comparison with the material from South Wales. For these opportunities, we have to thank the Curators in charge of the collections in the Museum of Practical Geology and the British Museum (Natural History).

This paper deals with the occurrence of all the known specimens of Xiphosura from the South Wales Coalfield. Special attention has been given to the stratigraphical distribution of these genera and species, and it is of interest to note from the material we have studied that they appear to be found at horizons which can be traced over a fairly extensive area. Regarding the vertical range of these forms an interesting fact emerges from our studies, namely, that *Belinurus*, *Prestwichianella* and *Euproops* have not been found together in South Wales, as happens in the English Coalfields. One specimen of *Euproops* is recorded from a horizon in the *Carbonicola ovalis* Zone. Species of *Belinurus* have been noted in the Measures from the Gwendraeth Seam up to the Cwmgorse Marine Beds. Above this level, *Prestwichianella* appears and ranges

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up to the Mynyddislwyn Vein. *Euproops* reappears in fair abundance near the top of the Pennant Series and in the measures from the Three Feet to the Mynyddislwyn seams (see Table, p. 114).

We wish to express our sincere thanks to Dr. A. E. Trueman for his helpful criticism of this paper during preparation.

History of the Genera

The name *Belinurus* was applied by König[1] in 1820 to a small Limulid found in an ironstone nodule from the Coal Measures of Coalbrookdale in Shropshire. The genotype *Belinurus bellulus*, however, was not described until 1836, when Buckland[2] figured the species from this classical locality as *Limulus trilobitoides*, a name used by Prestwich, Portlock and others.. In 1854, Pictet[3] revived König's genus, and Baily[4] working independently, employed the name in describing two new species in 1863.

Until 1866, all the Coal Measure Xiphosura were placed in the genus *Belinurus*, but in that year Woodward,[5] after a study of the species, concluded that they were readily divisible into two well-marked genera :—

(i) Forms with moveable thoracic segments and anchylosed abdominal ones. To this group he restricted the genus *Belinurus* with the species *B. bellulus*, *B. reginae* and *B. arcuatus*.

(ii) Forms with both thoracic and abdominal segments anchylosed and undivided. For these he established a genus which he named *Prestwichia* with *P. rotundata* as genotype and *P. anthrax* as another species.

In 1865, Meek and Worthen[6] had described a Coal Measure Xiphosurid under the name of *Belinurus danae*; later, Meek[7] transferred this species to a new genus, *Euproops*, in which he placed forms more or less intermediate in some characters between *Belinurus* and *Prestwichia*. *Euproops* agrees with *Prestwichia* in having the segments of the thoracetron (thorax and abdomen) fused, but differs from it in the quadrangular forms of the glabella and the position of the eyes, these being situated more anteriorly than in *Prestwichia*. Thus while Meek recognised three genera of Carboniferous Xiphosura, Woodward was only prepared to accept two.

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[1] König, C., Icones Fossilium Sectiles, pl. 18, fig. 230.

[2] Buckland, W., Bridgewater Treatise, vol. i, p. 396, vol. 2, 1836, pp. 77.

[3] Pictet, F. J., Traité de Paléontologie, Qd. ed., vol. 2, p. 538.

[4] Baily, W. H., ' Remarks on some Coal-measure Crustacea belonging to the genus *Belinurus*, König,' etc., *Ann. Mag. Nat. Hist.*, 3d ser., 11, pp. 107-114, 1863.

[5] Woodward, H., ' On some Points in the Structure of the Xiphosura, having reference to their relationship with the Eurypteridae,' *Quart. Journ. Geol. Soc.*, 1867, pp. 23, 31-33.

[6] Meek, F. B., and A. H. Worthen, March, 1865, *Proc. Acad. Philad.*; *Geol. Reports Illinois*, vol. ii, 1866, p. 365.

[7] Meek, F. B., *Amer. Journ. Sci. and Arts*, May, 1867. See also ' Notes on a New Genus of Fossil Crustacea,' *Geol. Mag.*, 1867, p. 230, and Meek, F. B., and A. H. Worthen, *Survey of Illinois* (*Palaeontology*), vol. iii, 1868.

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Before 1918, however, Woodward[1] came to the conclusion that *P. anthrax* and *P. rotundata* were generically distinct, and he placed the first-named with *Euproops*, and the name *Prestwichia* having been previously used as a genus of Hymenoptera by Lubbock in 1863, he proposed the name *Prestwichianella* for those forms which are allied to the genotype *P. rotundata*.

BELINURUS

Diagnosis.—Body limuloid, head-shield or prosoma semi-circular with long genal spines from the posterior angles. Median part of prosoma (glabella) prominent and divided into two lobes, declining towards the circumference and surrounded by a narrow flattened margin. Mesosoma, consisting of five free segments, each produced laterally into spines. Metasoma small, formed of three fused segments, and a long telson. Geno-holotype, *B. bellulus* König.

Belinurus concinnus sp. nov.

Fig. 1.

This specimen was collected by Mr. W. D. Ware from shales associated with the Brass Vein at the Diamond Colliery, Ystradgynlais. The specimen consists of a fairly well-preserved head-shield and the greater portion of the thoracetron.

Dimensions.—

Length of prosoma, 11 mm.
Breadth of prosoma, 18 mm.
Length of glabella, 9 mm.
Length of prosoma and thoracetron, 17·5 mm.
Breadth of glabella, 6 mm.
Estimated breadth of thoracetron, 13 mm.
Breadth of axis of thoracetron, 3·5 mm.

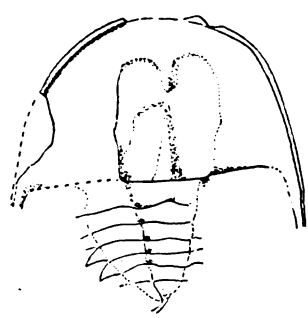

FIG. 1.—*Belinurus concinnus* sp. nov. (x 2).

The head-shield (prosoma) is nearly semi-circular in outline, the posterior portion being produced into genal spines of which only a

[1] Woodward, H., 'Notes on some Fossil Arthropods from the Carboniferous Rocks of the Cape Breton, Nova Scotia,' etc., *Geol. Mag.* vol. lv, 1918, p. 468.

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portion of one is preserved. This genal spine projects downwards and is almost parallel to the thoracetron. Around the prosoma, the posterior margin of which is nearly straight, is a well-defined flattened border about one millimetre in width. The glabella is well shown, and in size is large in relation to the prosoma. The ophthalmic lines are marked; two lateral eyes, and also the position of a third median eye is indicated on the ridge, which divides the glabella into two lobes.

The thoracetron is distinctly trilobed. It is imperfectly preserved, but six free thoracic segments can be seen. Each segment is terminated by a short, blunt spine. The axis of the thoracetron is of the same width as that of the posterior margin of the glabella, which measures 5 mm., but diminishes to 3·75 mm. near the telson. There is a small coalesced caudal portion bearing a tubercle above the point of insertion of the telson. The latter is about 1 mm. in breadth, but since it is only imperfectly preserved, its exact length cannot be ascertained. We have named this species *Belinurus concinnus*.

The long head-shield, which is more than half the length of the animal (minus the telson) serves to distinguish *B. concinnus* from other species. It shows some points of resemblance with *B. trechmanni* Woodward in the broad, almost parallel side axis of the thoracetron, and also in the presence of six free segments. Our specimen differs from this species in possessing posteriorly projecting genal spines, and in the marked difference in the shape of the head-shield. In *B. trechmanni* Woodward, the glabella is about two-thirds the length of the cephalon; in *B. concinnus* it is longer.

The holotype of this species is preserved in the Museum of Practical Geology, London, and is registered 48775.

B. carwayensis sp. nov.

Fig. 2.

In some blue shale from the roof of a thin seam above the Hwch Vein at Carway Colliery, Carmarthenshire, an almost complete specimen of *Belinurus* was collected.[1] Associated with it were shell fragments, chiefly those of *Naiadites*, and plant remains, including *Lepidophyllum sp.*

Dimensions.—

Length of prosoma, 8 mm.
Breadth of prosoma, 15·5 mm.
Length of thoracetron, 5·5 mm.
Breadth of thoracetron at posterior margin of prosoma, 11 mm.
Length of glabella, 4·5 mm.
Breadth of glabella, 4 mm.
Estimated length of genal spine, 5 mm.
Breadth of axis of thoracetron, 3 mm.
Breadth of anterior thoracic segment, 2·5 mm.
Length of longest thoracic spine, 1·75 mm.

[1] Dix, Emily, 'The Coal Measures of the Gwendraeth Valley and Adjoining Areas,' *Proc. South Wales Inst. Eng.*, vol. xliv, No. 5, 1928, p. 479.

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The prosoma is semi-circular in outline, with the posterior angles extended into fairly long genal spines. These spines make an angle of about 100 degrees with the posterior margin of the prosoma which is almost straight. The glabella is not well-preserved, but the two lobes and one of the lateral eyes can be distinguished. The posterior margin of the head-shield measures 16 mm. in breadth across the genal spines. The mesosoma is much narrower, distinctly trilobed, and is more or less semi-circular in outline. It is composed of five free segments diminishing in breadth from the anterior backwards. Each of the segments is terminated on either margin by a stout slightly recurved spine. The metasoma is small, with two segments terminated as spines. The telson is not preserved.

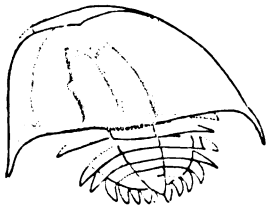

FIG. 2.—*Belinurus carwayensis* sp. nov. (x $1\frac{5}{6}$).

In the characters of the prosoma *B. carwayensis.* resembles *B. trechmanni* Woodward. It agrees with that species in general shape although the head-shield in the specimen from Carway is much bigger in proportion to the thoracetron, while the angle between the genal spine and the posterior margin of the prosoma is similar in the two species. *B. carwayensis,* however, differs from *B. trechmanni* in other characters and resembles *B. bellulus* König, *B. arcuatus* Baily and *B. baldwini* Woodward in having a narrower thoracetron in comparison with the posterior margin of the cephalon. The central axis of the thoracetron of our species is well defined and it agrees with *B. bellulus* Woodward and *B. arcuatus* Baily in being narrower than the width of the glabella. No tubercles are seen on the segments of the thoracetron.

The specimen taken as holotype has been presented to the Geological Department, National Museum of Wales (No. 29,197, G 3.).

Belinurus truemani sp. nov.

Fig. 3.

A small Belinurid was found in blue shale at a depth of 1,280 feet (about 260 feet below the Red Vein), in a borehole at Cwmgorse.[1]

[1] Davies, D. F., E. Dix, and A. E. Trueman, 'Boreholes in Cwmgorse Valley,' *Proc. South Wales Inst., Eng.*, vol. xliv, p. 37.

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Dimensions.—

Breadth of prosoma, 6 mm.
Length of prosoma, 2·5 mm.
Length of prosoma and thoracetron, 4·5 mm.
Length of glabella, 2 mm.
Breadth of glabella, 3 mm.
Length of genal spine, 2 mm.
Breadth of thoracetron at the anterior margin, 3·5 mm.

In general form it is broadly ovate, with a convex axis. The prosoma is nearly three times as broad as long, and is more or less oval in outline. The glabella is well-marked by three grooves, the central one being broadest and dividing the glabella into two lobes. The two outer grooves mark the ophthalmic lines on which are seen the impressions of the two lateral eyes, situated near the anterior margin. The ophthalmic ridges are produced into short neck spines about 2 mm. in length.

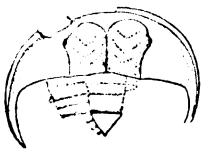

FIG. 3.—*Belinurus truemani* sp. nov. (x 4).

The glabella is large in relation to the prosoma and extends almost to the anterior edge of the prosoma. The cephalic shield is surrounded by a narrow flattened margin, the posterior angles being projected into long incurved genal spines.

The mesosoma is small, distinctly trilobed, and composed of four free segments which are terminated in blunt spines. The metasoma, which is well marked, is roughly triangular in shape and is apparently made up of three fused segments ; there are three spines on each side of the caudal area. The telson is missing, so that it is impossible to state the length it attained.

Belinurus truemani differs from all known species of *Belinurus* in the shape of the cephalon, the forward position of the eyes, the long incurved genal spines, in having only four free segments in the mesosoma and in the peculiar caudal area.

The holotype of this species has been presented to the Geological Department, National Museum of Wales (No. 29,197, G.1.).

Belinurus pustulosus sp. nov.

Fig. 4.

An interesting fragment of a Xiphosurid representing the greater portion of a head-shield was found in grey shale from the roof of the Stanllyd Seam at the Carway Colliery, Carmarthenshire.[1] The

[1] Dix, Emily, 'The Coal Measures of the Gwendraeth Valley and Adjoining Areas,' *Proc. South Wales Inst., Eng.*, vol. xliv, no. 5, p. 480.

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specimen shows a negative impression only, but in the following description the details given are those of the positive.

Dimensions.—

Estimated breadth of prosoma, 30 mm.
Length of prosoma, 12 mm.
Length of glabella, 9 mm.
Breadth of glabella lobes near orbits, 4 mm.

The prosoma is more than twice as broad as long. The front margin is gently curved, and the posterior margin is practically straight. The head-shield is surrounded by a narrow raised rim, which is well shown around the genal spines and the posterior margin. Outside this rim is a narrow flattened area. The genal spines are moderately long, making an angle of about 120 degrees with the posterior margin of the prosoma. The glabella in this specimen is well preserved. The ophthalmic ridges are prominent, and slightly curved in the region of the orbits ; one of the lateral eyes is well shown.

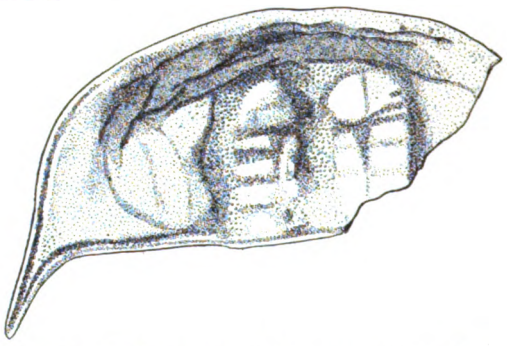

FIG. 4.—*Belinurus pustulosus* sp. nov. (x $2\frac{2}{3}$).

The characteristic feature of this specimen, however, is the segmentation of the glabella, which shows traces of five or possibly six segments. The glabella is divided along the middle line into two well-defined lobes, each being again divided by a longitudinal ridge which extends for about two-thirds of its length. In this posterior portion of the glabella are three well-marked segments and a feeble fourth posterior segment ; in the anterior part of the glabella, which forms a depressed area, are traces of two feebly marked segments.

A fine pitting, indicating the pustulose character of the ornament, is seen where the surface of the head-shield is well preserved, particularly along the genal spine, the ophthalmic ridges and the ridges of the glabella.

Outside the lateral margins of the glabella is a shallow, slightly depressed area bounded by a distinct curved line.

This specimen differs from other species of *Belinurus* in having distinct segmentation of the glabella, in which character it resembles

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Paleolimulus avitus of Dunbar[1]. The pattern of the glabella in *Belinurus pustulosus* is markedly different from that of *P. avitus*. Segmentation of the glabella is also known to occur in a species of *Euproops*, namely *E. amiae* Woodward.

Other features which serve to distinguish our specimen from other species of *Belinurus* are the depressed anterior portion of the glabella, the pustulose ornament of the head-shield, and the distinct raised border of the head-shield.

As our specimen is incomplete there is some doubt as to its true affinity, but from the characters available it appears to be more closely allied to *Belinurus* than to any other existing genus. It may possibly represent a new genus intermediate in characters between *Belinurus* and *Paleolimulus*.

The specimen, the holotype of the species, has been presented to the National Museum of Wales, and is registered 29,197, G2.

Belinurus bellulus König

Fig. 5.

A well-preserved specimen of *Belinurus* was found in some blue shale from the roof of the Gwendraeth Vein at the Glyn-Hebog Colliery, Carmarthenshire.[2] It consists of an almost complete prosoma, and the three anterior segments of the mesosoma. The specimen agrees in all its characters with *B. bellulus*, and we refer it without any hesitation to König's species.

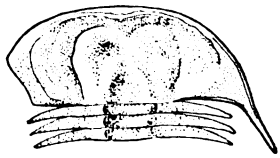

FIG. 5.—*Belinurus bellulus* König (x 2¾).

At this locality *B. bellulus* is associated with fresh-water shells, including *Naiadites modiolaris* (J. de C. Sow.), and fragments of plants. Another fragment of *Belinurus* was found, but it is too small to permit the identification of the species to which it belongs.

Our specimens are now in the collection of the University College of Swansea.

Belinurus sp. (? *B.* cf. *bellulus* König.)

A portion of the prosoma of a Belinurid was collected from some dull grey shale passed through at a depth of 1,271 feet, about 251 feet below the Red Vein, in No. 1 Borehole at Cwmgorse.[3]

[1] Dunbar, Carl O., 'Kansas Permian Insects.' Part 2. *Paleolimulus*, etc. *The American Journal of Science*, vol. v, 1923, p. 443.
[2] Dix., E., *ibid.*, p. 463.
[3] Davies, D. F., E. Dix and A. E. Trueman, *ibid.*, p. 37.

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The prosoma has a narrow flattened margin, and has two fairly long genal spines. A portion of the glabella is preserved, showing two lobes. The exact identification of the specimen, however, is impossible owing to its fragmentary nature, but the characters of the prosoma suggest affinities with *B. bellulus* König.

Belinurus arcuatus Baily

Fig. 6.

This specimen was collected from some dark blue shale from the roof of the Rock Vein, Blaina Colliery, Pantyffynon. Associated with it were fragments of the shells of *Anthracomya* and plant fragments, including *Calamites sp.*

The specimen shows an almost complete prosoma together with two segments of the mesosoma. Other segments of the thoracetron are possibly preserved underneath the prosoma, thus giving rise to the ridges seen on the lateral areas of the head-shield.

Dimensions.—

Length of prosoma, 7 mm.
Breadth of prosoma across genal spines, 13 mm.
Length of glabella, 5·1 mm.
Breadth of glabella, 4 mm.
Length of genal spine, 3·5 mm.
Breadth of thoracetron, 7 mm.
Breadth of axis of thoracetron, 2·25 mm.

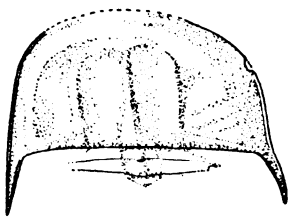

FIG. 6.—*Belinurus arcuatus* Baily (x $2\frac{3}{4}$).

The prosoma is semi-circular in outline, slightly elevated, and surrounded by a narrow flattened margin. The posterior angles of the prosoma are produced into long genal spines making an angle with the posterior border of the cephalon comparable with that of the type of the species. In our specimen from Pantyffynon the glabella is well-marked and is a little over two-thirds the length of the prosoma as in the type of *B. arcuatus*. The ophthalmic ridges are slightly curved showing the position of the two lateral eyes, and one of the ridges appears to be produced to form a short neck spine. The width of the thoracetron is small in comparison with that of the prosoma as in *B. bellulus* ; the central axis also is narrow, one of the characteristic features of this species.

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The Pantyffynon specimen is closely similar in many characters to *B. arcuatus* Baily, and although the prosoma is slightly longer than in the type species, a difference which may be due to preservation, we have no hesitation in referring it to *B. arcuatus*.

The specimen is preserved in the collection of the University College of Swansea.

Belinurus cf. *arcuatus* Baily

Fig. 7.

A well-preserved head-shield of a Belinurid was collected by Mr. W. D. Ware from the roof shales of the Brass Vein at the Diamond Colliery, Ystradgynlais. The dimensions of this specimen are as follows :—

Length of prosoma, 6·5 mm.
Breadth of prosoma across genal spines, 13 mm.
Length of glabella, 4 mm.
Breadth of glabella (near eyes), 4·5 mm.
Length of genal spine, 4 mm.
Length of neck-spine, 1·25 mm.

The prosoma is semi-circular in shape, with the anterior margin gently curved ; it is slightly elevated, declining towards the circumference, and surrounded by a narrow flattened margin. The glabella is well-defined and divided into two lobes ; the ophthalmic ridges are slightly curved, showing the position of two lateral eyes. These ridges are continued across the posterior margin of the head-shield and form neck spines about 1½ mm. in length. The posterior margin of the cephalon, on either side of the glabella, slopes anteriorly. The genal spines are long, making an angle of about 95 degrees with the posterior margin of the head-shield.

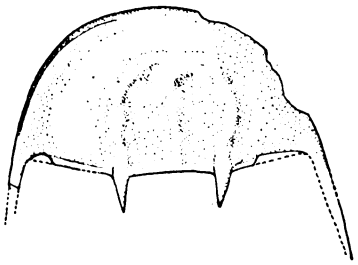

FIG. 7.—*Belinurus* cf. *arcuatus* Baily (x 3½).

In shape, the prosoma is more orbicular than that of *B. reginae* Baily or of *B. bellulus* König, and it also differs from these species in the presence of two neck spines, similar to those seen in *B. arcuatus* Baily. It is distinguished from the last mentioned species, however, in the gently curved anterior margin of the prosoma, and further, the posterior margin, which is straight in *B. arcuatus* Baily, slopes anteriorly on either side of the glabella in our specimen.

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Apart from these minor differences, we think our example from Ystradgynlais is closely allied to Baily's species, and until additional material is available for study, we suggest that it be compared with *B. arcuatus*.

The specimen is preserved in the collections of the Museum of Practical Geology, Reg. No. 48774.

Belinurus cf. *königianus* Woodward

Fig. 8.

A Belinurid closely resembling *B. konigianus* Woodward was obtained from a bed of shale at a depth of 1,466 feet in No. 1 borehole at Cwmgorse.[1] The horizon is about 454 feet below the Red Vein, in

FIG. 8.—*Belinurus* cf. *königianus* Woodw. (x 2).

the zone of *Anthracomya pulchra*. Unfortunately, only the prosoma is preserved, but as will be seen from the figure, the characters of the head-shield are almost identical with those of *B. königianus* Woodward.

Belinurus sp. (? *B. reginae* Baily)

Associated with fragments of fresh-water shells, a fragment of a Belinurid was collected by Dr. A. E. Trueman from dark blue shale from the roof of the Brynlloi Seam at the Pontyclerc Colliery, Pantyffynon, Carmarthenshire. Only five free thoracic segments and an anchylosed caudal portion are preserved. The mesosoma shows the typical trilobed appearance and the central axis is well-marked. The free segments terminate in blunt slightly curved spines. On four of the free segments a small tubercle is seen, similar to those found in *B. reginae* Baily.

Belinurus sp.

This specimen was found in blue shale forming the roof of the Brasslyd Seam at the Pentre Mawr Colliery, Carmarthenshire[2]. It consists of an incomplete cephalic shield on which the glabella with the ophthalmic ridges and lateral eyes are well shown, but the other portion is so poorly preserved that specific identification is impossible.

[1] Davies, D. F., E. Dix and A. E. Trueman, *ibid.*, p. 37.
[2] Dix, E., *ibid.*, p. 465.

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PRESTWICHIANELLA 1918=PRESTWICHIA

Diagnosis :—Prosoma semicircular, continued into spines at the posterior angles ; median raised part (glabella) broad, divided along the centre by the axial furrow, and by two other slightly diverging parallel lines on either side of the axis, reaching nearly half-way to the frontal border, where they are arcaded, forming a rounded raised confluent line in front of the glabella. The circular line seen outside the border of the glabella may indicate the impression of the line of the broad incurved under-margin of the head-shield.[1] Compound eyes are situated on the anterior lateral angles of the glabella. The thoracic abdominal segments, usually seven, are fused together to form a shield, with a flat marginal part produced into short spines and a long tail spine. The central axis of the body segments is narrow.

Prestwichianella nitida sp. nov.

Fig. 9.

The highly fossiliferous grey shales from the roof of the Graigola Seam yielded an abundant flora and fauna at the Clydach Merthyr Colliery, and the remains of arthropods were also particularly abundant : these included *Euphoberia sp.*, *Orthomylacris lanceolata* Bolton, *Hemimylacris sp.*, *Euproops graigolae* sp. nov., and the new species of *Prestwichianella* described below.

Dimensions.—

Estimated length of prosoma, 14 mm.
Estimated breath of prosoma, 28·5 mm.
Length of glabella, 11 mm.
Breadth of glabella lobes near the eyes, 13 mm.
Breadth of glabella lobes at posterior margin, 9·5 mm.
Length of mesosoma (preserved), 8 mm.
Estimated breadth of thoracetron, 23 mm.
Breadth of marginal fringe, 3·25 mm.
Breadth of central axis of thoracetron, 3·25 mm.

The prosoma, which is incomplete, is probably more than twice as broad as long, and is nearly semicircular in outline. Only a fragment of one of the genal spines is preserved, but this gives some indication of the proportions of the prosoma. The glabella is quadrangular in outline, and is slightly raised. The eyes appear to be placed on the anterior lateral angles but they are not well shown. A portion of the glabella is divided into two lobes by means of a narrow raised ridge, which broadens and becomes flattened at the posterior margin.

About 3 millimetres from the anterior margin of the glabella lobes two ridges are developed at right angles to the median ridge (of the glabella) ; these ridges are about two millimetres in length

[1] Woodward, H., ' Notes on some Fossil Arthropods from the Carboniferous Rocks of Cape Breton, Nova Scotia,' etc., *Geol. Mag.*, vol. 55, p. 469, 1918.

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and they diverge gradually beyond the median ridge to join the lateral posterior margin of the glabella. On either side of the lateral margins of the glabella lobes are two faint curved lines, which appear to join the posterior margin of the prosoma, and a curved line outside these lobes can also be seen on the specimen. One lateral margin of the glabella lobe appears to be produced into a short neck spine.

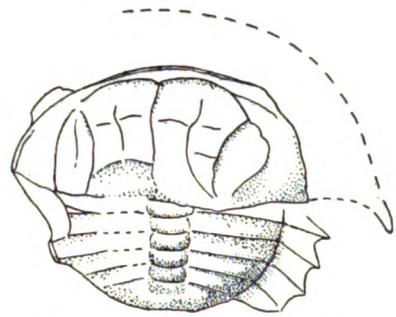

FIG. 9.—*Prestwichianella nitida* sp. nov. (x 2).

The thoracetron, which articulates along the anterior margin of the prosoma, is about three times as broad as long. The mesosoma is distinctly trilobed and consists of six coalesced segments which decrease in length posteriorly. The ridges and furrows of each segment are marked on the narrow central axis, and they curve slightly backwards. Each segment terminates in a prominent marginal spine; the spines are united to each other by a broad membrane, beyond which they slightly project. The third segment from the anterior margin of the thoracetron is ornamented with a large blunt tubercle.

Unfortunately the abdominal segments and the telson are not preserved.

Prestwichianella nitida differs from *P. rotundata* Prestwich in the characters of the head-shield. In *P. rotundata* the length of the glabella lobes is only about half that of the prosoma and also half the length of the thoracetron. In *P. nitida* the length of the glabella lobes is probably more near two-thirds that of the prosoma and is equal to the length of the thoracetron. The shape and character of the thoracetron are similar in both species, but the marginal fringe in *P. nitida* is wider than in *P. rotundata* and the spines are shorter.

The specimen taken as holotype is preserved in the collections of the Museum of Practical Geology, Reg. No. 48532.

Prestwichianella rotundata (Prestwich)

We have not been able definitely to recognise the presence of this well-known species of *Prestwichianella* in the South Wales Coalfield, although specimens from four localities show affinities close enough

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to suggest comparison with it. The difficulty has been mainly due to the fragmentary nature of our material.

One specimen from the roof-shales of the Hughes Vein at Kilvey Hill shows a portion of the prosoma attached to an almost complete thoracetron, and the latter strongly resembles that of Prestwich's species.

Another example from the roof of the Mynyddislwyn Vein, formerly worked at the Gelli-deg Level, Maesycwmmer, exhibits only a portion of the mesosomatic and metasomatic segments, but their characters strongly suggest affinities with *P. rotundata* Prestwich. The fragment had been previously identified as *P.* cf. *rotundata* by Mr. E. T. Newton, F.R.S.,[1] but we cannot give a definite determination on account of its incomplete state of preservation. This specimen and its counterpart are preserved in the collection of the Museum of Practical Geology, and are numbered 25423 and 48522 respectively.

Two specimens, collected by Mr. David Davies, one from the roof of the Six Feet Vein at the Cae Duke Colliery, near Swansea, and the other from the Upper Gelli Seam, Pontardulais, are preserved in the collections of the National Museum, Cardiff, and are registered as 27,177,G4 and 27,177,G5. The example from the Cae Duke Colliery consists of the thoracetron attached to a fragment of the prosoma. The central axis of the thoracetron is well shown, and each of the six fused segments bears a small tubercle; the seventh segment has a more prominent tubercle, as in the type of the species. In our specimen the marginal spines extend only a short distance beyond the fringe.

Prestwichianella sp.

A well-preserved thoracetron of *Prestwichianella*, now in the collections of the Welsh National Museum and numbered 27,177,G2, was found by Mr. D. Davies, F.G.S., in an ironstone nodule at the base of the Staffordian Series at Gilfach Goch. Six segments are shown, and each bears a tubercle on the central axis. A characteristic feature of this specimen is the broad marginal fringe of the thoracetron.

Until more details are obtained from additional material, we refer the specimen provisionally to the genus *Prestwichianella*.

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Diagnosis: Prosoma semicircular, continued into genal spines which curve upwards and outwards from the posterior border of the head-shield. Median raised portion of the prosoma (glabella) is quadrangular, with the compound eyes situated on its anterior lateral angles. The mesosomatic and metasomatic segments, usually seven in number, are united together forming a shield, with a flat marginal part produced into spines, and a long tail spine.

[1] 'The Country around Merthyr Tydfil,' Pt. v (*Mem. Geol. Surv.*), 1904, p. 78.

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Euproops graigolae sp. nov.

Fig. 10.

This specimen was found associated with *Prestwichianella nitida* in shales from the roof of the Graigola Seam at the Clydach Merthyr Colliery (see p. 101). It is nearly complete, only a portion of the telson and the genal spines being not preserved.

Dimensions :—

Length of prosoma, 10 mm.
Breadth of prosoma across the genal spines, 20 mm.
Length of glabella, 6·5 mm.
Breadth of glabella between the eyes, 8·5 mm.
Breadth of glabella at the posterior margin of the prosoma, 6 mm.
Length of thoracetron, 11 mm.
Breadth of thoracetron including marginal fringe, 17·5 mm.
Breadth of marginal fringe, 3 mm.
Breadth of central axis, 3 mm.

The prosoma is almost semi-circular in shape, with the posterior angles produced into short genal spines. The frontal border is narrow and slightly flattened. The posterior margin curves slightly anteriorly to meet the lateral margins of the prosoma in the genal spines.

The glabella is well-preserved; it is 6 millimetres wide at the cervical border, and it widens to 8·5 millimetres across the line of the orbits. It forms a double arch in front, and is united in an acute V-shaped, posteriorly directed ridge in the central line; this ridge extends backwards to the posterior margin of the prosoma, dividing the glabella into two lobes. About 1 millimetre on either side of the median ridge, two other faint ridges are developed, and these extend anteriorly for about 3 millimetres, and then turn at right angles to join the median line. The lateral margins of the glabella are produced and form neck spines.

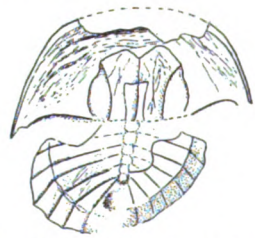

Fig. 10.—*Euproops graigolae* sp. nov. (x 1½).

The thoracetron articulates along its anterior border with the posterior margin of the prosoma. It is slightly elevated and is almost cordiform in shape. The thoracetron is distinctly trilobed and is made up of six equal segments. The specimen originally showed the central axis, which was very narrow, being less than 3 millimetres broad at the cervical border, and equal in width to the

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smaller lobes of the glabella; it decreases in width posteriorly to about 1½ millimetres. Unfortunately in dissecting out further details of the thoracetron a portion of the anterior segments and the central axis were destroyed. The segments are about 1½ millimetres wide and are terminated in well-marked spines, which are united together to form a marginal fringe. The extremities of the spines are not preserved in this specimen, but they probably extended some distance beyond the fringe.

The abdomen is poorly preserved and probably consists of two fused segments. The length of the telson is unknown.

Compared with the type of *Euproops* (*E. danae* Meek and Worthen) the prosoma of *E. graigolae* is longer from back to front; the glabella is smaller in proportion to the prosoma, but the angle which the genal spine makes with the posterior margin of the prosoma is closely similar to that of the genotype. The shape of the thoracetron in our specimen differs from *E. danae* Meek and Worthen and resembles that of *E. amiae* Woodward. The marginal fringe is well-developed in *E. graigolae*, but the extent of the spines beyond the fringe is unknown. The surface of the prosoma and the marginal fringe in *E. graigolae* appears to be striated.

The holotype of this species is preserved in the Museum of Practical Geology and is numbered 25424.

Euproops gwenti. sp. nov.

Fig. 11.

A good specimen of *Euproops* with its counterpart was collected from dark grey shale from the roof of the Mynyddislwyn Seam, Gellideg, Monmouth. Associated with it were a rich flora and other interesting fossils, including *Archimylacris sp.*, *Palaeoxyris* cf. *carbonaria* and *Diplodus gibbosus*.

Dimensions.—

Estimated length of prosoma, 16 mm.
Breadth of prosoma, 27·5 mm.
Length of glabella, 11 mm.
Breadth of glabella near orbits, 10 mm.
Breadth of glabella at posterior margin of prosoma, 8 mm.
Length of genal spine, 10 mm.
Length of thoracetron, 13 mm.
Breadth of thoracetron (minus fringe), 18 mm.
Breadth of central axis, 2·5 mm.
Breadth of marginal fringe (preserved), 1·5 mm.
Length of telson, unknown.

The characters of the head-shield of our specimen readily distinguish it from other species of *Euproops*. Unfortunately, a portion of the prosoma near the anterior margin is not preserved, but from the details available it may be concluded that the prosoma is probably semi-circular in shape. A well-defined flattened area is seen along the posterior margin of the prosoma, and is continued around the

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genal spines; it probably extended around the anterior margin of the prosoma. The posterior angles of the head-shield are produced into long genal spines. The central portion of the posterior margin of the prosoma (that is, in the region of the glabella) is straight, but on either side it slopes anteriorly forming an angle of about 95 degrees with the genal spines. In this character it is similar to *E. amiae* Woodward, and intermediate between *E. danae* Meek and Worthen and *E. anthrax* Woodward.

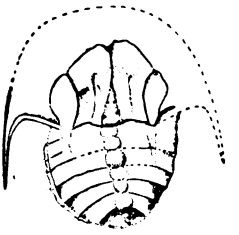

FIG. 11.—*Euproops gwenti* sp. nov. (nat. size).

The gabella is quadrangular and resembles that of *E. danae* and that of the specimen figured as *Prestwichia rotundata* Prestwich by Mr. G. C. Greenwell, F.G.S.[1] The glabella, which is slightly raised, is 11 millimetres in length, and 10 millimetres wide across the orbits. The lateral margins of the glabella curve inwards and then slightly outwards to join the posterior margin of the prosoma, where they are 9·5 millimetres apart; the lateral margins are produced and form short neck spines. The position of the eyes cannot be determined in our specimen. The glabella is divided for half its length by a narrow raised ridge. Between the posterior margin of this ridge and the cervical border, is an area about 2·5 millimetres wide which appears to be a prolongation of the axis of the thoracetron. Faint traces of grooves are seen on this area similar to *E. amiae*. The area between the glabella and the margin of the prosoma shows a pustulose ornament.

The coalesced mesosomatic and metasomatic segments form a heart-shaped shield. The mesosoma consists of six segments which are marked by ridges. The spines or extremities of the segments are joined together by a membrane, only a small portion of which is seen in the specimen. The axis of the thoracetron is narrow and each segment is ornamented with a tubercle. It is impossible to make out the number of segments in the metasoma, but the axis just above the insertion of the telson is ornamented with one large tubercle. The telson is not preserved.

In general shape, and in the characters of the glabella *E. gwenti* shows affinities to *E. danae*, but it differs from this species in the greater angle between the posterior margin of the prosoma and the

[1] Greenwell, G. C., 'On *Prestwichia* found in the Coal Measures of East Somersetshire,' *Trans. Manch. Geol. Soc.*, vol. vi, p. 123, 1866-7.

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anterior margin of the thoracetron, in which character it resembles *E. amiae*. It, however, differs from *E. amiae* in having a narrower axis to the thoracetron and also in the shape of the thoracetron. *E. gwenti* is readily distinguishable from other species of the genus by the pustulose character of the prosoma.

The holotype of this species and its counterpart are preserved in the Museum of Practical Geology, and are registered 48523, and 48524.

Euproops islwyni sp. nov.

Fig. 12.

This specimen, with a portion of its counterpart, was found in association with *E. gwenti* sp. nov., in grey shale from the roof of the Mynyddislwyn Seam, Gellideg, Monmouth. Two well-preserved fragments of the head-shield and a portion of the thoracetron are preserved. In the specimen numbered 48526 a portion of the prosoma is doubled under the thoracetron. The characters described are those of the positive.

Dimensions.—

Estimated length of prosoma, 16 mm.
Breadth of prosoma across genal spines, 34 mm.
Length of glabella, 9·5 mm.
Breadth of glabella between the orbits and at the cervical border, 12·5 mm.
Length of genal spine, 9·5 mm.

The prosoma is almost semicircular in shape and is surrounded by a narrow flattened border. The posterior margin of the prosoma slopes gently anteriorly on either side of the glabella, and meets the lateral margins in the genal spines. The prosoma most closely resembles that of *E. scheeleana* Ebert, in the angle which the posterior margin of the prosoma makes with the genal spine and also in the long, thin, slightly incurved genal spines as seen in one of Ebert's figures. It differs from this species, however, in the form and markings of the glabella.

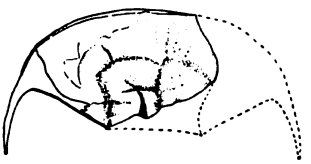

FIG. 12.—*Euproops islwyni* sp. nov. (nat. size).

The glabella is not quite so quadrangular as in other species of this genus. It is divided by a median ridge into two lobes, which are again partially divided into two more lobes at right angles to the median range. The position of the eyes cannot be determined owing to the state of preservation.

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Only a portion of five of the segments and the axis of the mesosoma are preserved. The segments are nearly 2 millimetres wide, and curve very slightly posteriorly. To this species we give the name *Euproops islwyni*.

The holotype of this species with its counterpart are preserved in the Museum of Practical Geology and are numbered 48526 and 48525 respectively.

Euproops meeki sp. nov.

Fig. 13.

A specimen of *Euproops* was collected from shales from the roof of the Mynyddislwyn Seam, at the Gwernau Level, three-quarters of a mile S.E. of Maesycwmmer. Unfortunately only the prosoma and its counterpart are preserved. It resembles the prosoma of *E. anthrax* Woodward, but there are important differences.

Dimensions.—

Length of prosoma, 13 mm.
Breadth of prosoma, 38 mm.
Length of glabella, 9·5 mm.
Estimated width of glabella, 20 mm.
Distance between neck spines, 10 mm.

The prosoma is almost elliptical in shape, with the frontal margin well marked as in *Belinurus reginae* Baily and *E. anthrax* Woodward. The genal spines, which are not well shown in our specimen, are developed from the sides of the prosoma as in *E. anthrax*. The posterior margin of the glabella is marked by two short neck spines, on either side of which the margin of the prosoma slopes anteriorly and meets the lateral margin of the prosoma in the genal spines.

The characters of the glabella are not well shown, and only a faint trace of the two lobes can be distinguished.

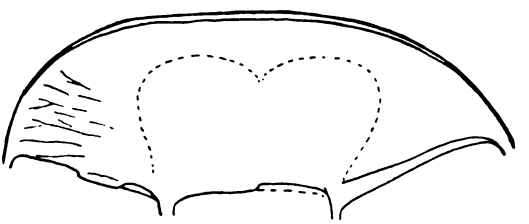

FIG. 13.—*Euproops meeki* sp. nov. (x 1¾).

In *E. meeki* the genal spines appear to curve posteriorly as in some other species of *Euproops*, and in this character it differs from *E. anthrax*, in which the genal spines are outwardly directed. Our specimen also differs from *E. anthrax* in the shape of the prosoma, it being more elliptical than in that species. Unfortunately the thoracetron is missing and it is also impossible to compare the glabella of this form with that of other species of *Euproops*.

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The specimens, the holotype of this species and its counterpart, are preserved in the Museum of Practical Geology, and are numbered 48528 and 48529 respectively.

Euproops cambrensis sp. nov.

Fig. 14.

A well-preserved specimen of *Euproops* was collected by Mr. T. Llewelwyn in dark grey shale from the roof of a seam 15 yards above the New Seam (which is considered to be the equivalent of the Gellideg Seam), at the Ocean Colliery, Blaengarw, north of Bridgend. Associated with it are a number of plant fragments, including *Cordaites sp.*

Dimensions.—

Length of prosoma, 19 mm.
Breadth of prosoma across the genal spines, 41 mm.
Length of glabella, 13·5 mm.
Breadth of glabella near the orbits, 12 mm.
Breadth of glabella at the posterior margin of the prosoma, 9·5 mm.
Length of genal spine (preserved), 11 mm.
Estimated length of neck spines, 11·5 mm.
Distance between neck spines near their extremities, 15 mm.
Length of thoracetron, 19 mm.
Estimated breadth of thoracetron at its anterior margin, 35 mm.
Breadth of marginal fringe, 5 mm.
Breadth of central axis near cervical border, 4·5 mm.
Breadth of one thoracic segment, 3·5 mm.
Length of mesosoma, 13 mm.
Length of metasoma, 6 mm.
Length of telson, unknown.

The prosoma is a little more than twice as broad as long; the anterior margin is only very gently curved for half the breadth of the prosoma, curving smoothly backwards into the genal spine. The frontal doublure is strongly marked as in *Euproops anthrax* Woodward and *Belinurus reginae* Baily. The posterior margin of the prosoma on either side of the neck spines slopes anteriorly to meet the inner border of the genal spines at an angle of about 90 degrees. The genal spines are broad. The border of the prosoma is slightly raised to form a narrow raised rim, which continues along the anterior half of the genal spine when it becomes faint and finally disappears about 2 millimetres from the end of the spine.

The glabella is well shown; it is quadrangular in shape, and is more than two-thirds the length of the prosoma. It is divided into two distinct lobes by means of a well defined median ridge, which is nearly as wide as the axis of the thoracetron. The position of the eyes cannot be determined in the specimen. The lateral margins of the glabella are slightly re-entrant, the posterior portion being produced to form long, and slightly diverging neck spines which extend almost to the posterior margin of the mesosoma.

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There are traces of punctation on the anterior portion of the glabella and on the surface of the prosoma near the glabella margin. The front of the prosoma is, like the thoracetron, finely granular or pustulose.

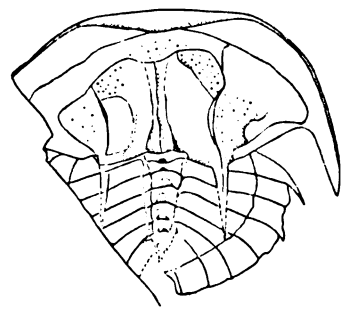

FIG. 14.—*Euproops cambrensis* sp. nov. (nat. size).

The thoracetron is distinctly trilobed, and is nearly semi-circular in outline. The central axis is well marked and is narrow in proportion to the prosoma. The thoracetron is composed of six nearly equal coalesced segments, the ridge and furrow of each can be seen on the central axis. Each segment is produced into a spine which extends across the membraneous margin of the thoracetron. Six of the spines are strongly marked, and a seventh, an extension of the abdominal or metasomatic portion, is less clearly shown. These marginal spines appear to have been of almost equal length and to project backwards for about four millimetres beyond the margin of the membrane.

The abdomen or metasoma is not clearly shown in the specimen; the telson is not preserved.

The presence of tubercles along the central axis is indicated; the one on the first segment being well marked, and a broad base of a large tubercle is indicated near the point of insertion of the telson. The entire surface of the thoracetron is covered with small granules.

E. cambrensis can be distinguished from other species of *Euproops* by the shape of the prosoma. It most closely resembles that of *E. amiae* Woodward, but it differs from that form in that the genal spines are directed more posteriorly. It also differs in the form of the glabella, that of *E. amiae* having traces of segmentation and not being completely divided by a median ridge, while the axis of the thoracetron in *E. cambrensis* is narrower than in *E. amiae*. The membraneous margin of the thoracetron, however, is wider than in *E. amiae*, the species approaching in this character to *Prestwichianella rotundata* (Prestwich), from which it differs in many important features.

The holotype of this species has been presented to the Geological Department, National Museum of Wales (No 29,198, G1.).

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Euproops scheeleana (Ebert)

A specimen of a Xiphosurid was collected by Mr. T. H. Rowlands, M.Sc., from the roof of the Six Feet Seam at the Mynydd Newydd Colliery, Swansea.[1] It is preserved in a black shale containing numerous specimens of *Anthracomya* and *Lepidophyllum*.

Unfortunately, the glabella is in a poor state of preservation, but the shape of the head-shield, the character of the genal spines, and the wide marginal fringe of the thoracetron leaves little doubt as to its identity with Ebert's species.

This specimen is in the collection of the University College of Swansea.

Euproops cf. *anthrax* (Prestwich).

Three fragments of head-shields of *Euproops* were collected by Mr. T. H. Rowlands, M.Sc., in a small block of grey shale from a horizon near the Three Feet Seam, at the Copper Pit Colliery, Morriston, near Swansea.[2]

In one instance, the specimen represents a fragment of the prosoma showing the genal spine, a well-preserved glabella, and a small fragment of the thoracetron. This example agrees with *Euproops anthrax* (Prestwich) in the double frontal border of the cephalon and in the form of the hinder portion of the prosoma, which slopes anteriorly, so that the genal spines appear to rise from the centre of each side of the head. In our specimen, however, the genal spines are not so outwardly directed as in *Euproops anthrax*.

The glabella, which is not so quadrangular as in other species of *Euproops*, is divided into two distinct lobes by means of a median ridge. Unfortunately the position of the eyes cannot be determined. The Morriston specimen agrees closely with a form figured by Dr. H. Bolton as *E. anthrax* from the Kent Coalfield.[3]

The two other fragments are undoubtedly related to the specimen here described.

These specimens have been presented to the University College of Swansea.

Euproops sp. (Cf. *E. anthrax* (Prestwich))

Fig. 15.

A fragment of the head-shield of a Xiphosurid was obtained by Mr. D. Davies, F.G.S., from a black shale from the roof of the Swansea Four Feet Seam, at the Mountain Colliery, Gorseinon. It was associated with numerous leaves of *Cordaites*.

[1] Rowlands, T. H., ' The Correlation of the Coal Measures in the Western Portion of the South Wales Coalfield. Part III—The Upper Part of the Pennant Series of the Swansea District.' *Proc. South Wales Inst. Eng.*, vol. xli, 1925, p. 263.

[2] Rowlands, T. H., *ibid.*

[3] Bolton, H., ' The Fauna and Stratigraphy of the Kent Coalfield.' *Trans. Inst. Mining Engineers*, 1915.

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FIG. 15.—*Euproops sp.*
Cf. E. anthrax (nat. size).

This specimen appears to agree with *E. anthrax* in the character of the genal spines, which arise from the centre of each side of the head-shield. The glabella is well-shown, but since this is not exhibited in the type species of *E. anthrax* a comparison cannot be made. The glabella differs in shape, however, from other species of *Euproops*, being less quadrangular. In this character it shows an affinity with *Prestwichianella*.

The specimen is preserved in the National Museum of Wales and is registered 03605,27,177,G3.

Notes on other fragments which are referred to Euproops.

Several incomplete examples which appear to have closer affinities with *Euproops* than with *Prestwichianella* have been obtained at several localities, but in all cases the fragmentary character of the specimens renders it impossible to place them with certainty.

One specimen, a portion of the thoracetron, showing the long spines of the segments projecting beyond the marginal fringe, was collected from black shales associated with the Graigola Seam, east of Drummau Hill, near Neath. A number of specimens of *Leaia leidyi* were found in the same shales. In some respects the characters of the fragments suggest affinities with Meek and Worthen's species of *E. danae*. The specimen is preserved in the Museum of Practical Geology and is registered 20768.

Two examples, also in the Museum of Practical Geology, registered 48527 and 48530, were found in the roof shales of the Mynyddislwyn Seam at the Gwernau Level, Maesycwmmer. One, 48527, is a poorly-preserved, incomplete cephalon, and 48530 shows a portion of the thoracetron.

From the same horizon as the above, a fragment of the prosoma, somewhat crushed, was obtained at the Old Gelligaer Colliery, half a mile S.E. of Llancaiach Station. It was associated with *Leaia leidyi*, var. *salteriana* Jones, ostracods, *Anthracomya phillipsi* Will. and an abundant flora. This specimen is also in the collections of the Museum of Practical Geology, registered 48531.

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Euphoberia sp. nov.?

It seems also appropriate to notice in this paper the presence of the Myriapod, *Euphoberia* in the Coal Measures of South Wales. The specimen was collected by one of the writers in 1902, and was subsequently identified by Mr. E. T. Newton, F.R.S., as *Euphoberia armigera* Meek and Worthen. Recent studies of the fossil, however, lead us to regard it as belonging to a distinct but closely allied species. At the same time, the preservation of the specimen would hardly justify the description of it as a new species until additional material is available for study.

The specimen measures 35 mm. in length. The dorsal segments are badly crushed, and it is difficult to decipher the ornament or to ascertain the shape and size of each segment. The ventral segments, however, are well shown. These appear to be 1·5 mm. in breadth and 2 mm. in length, each carrying weakly-jointed legs 4 mm. long. The edge of each segment is slightly raised, and under a lens, each presents the appearance of those which are found in *Euphoberia granosa* Scudder.[1]

The Myriapod was obtained from shales associated with the Graigola Vein at the Clydach Merthyr Colliery, 500 yards W.S.W. of Pen-y-banc farm, Clydach, and was recorded as *E. armigera* in the memoir on the geology of the South Wales Coalfield, pt. vii. It was found in association with *Prestwichianella nitida*, *Euproops graigolae* and other arthropod remains.

[1] Scudder, S. H., 'The Fossil Insects of North America,' vol. i, 1890, pl. 9, fig. 22.

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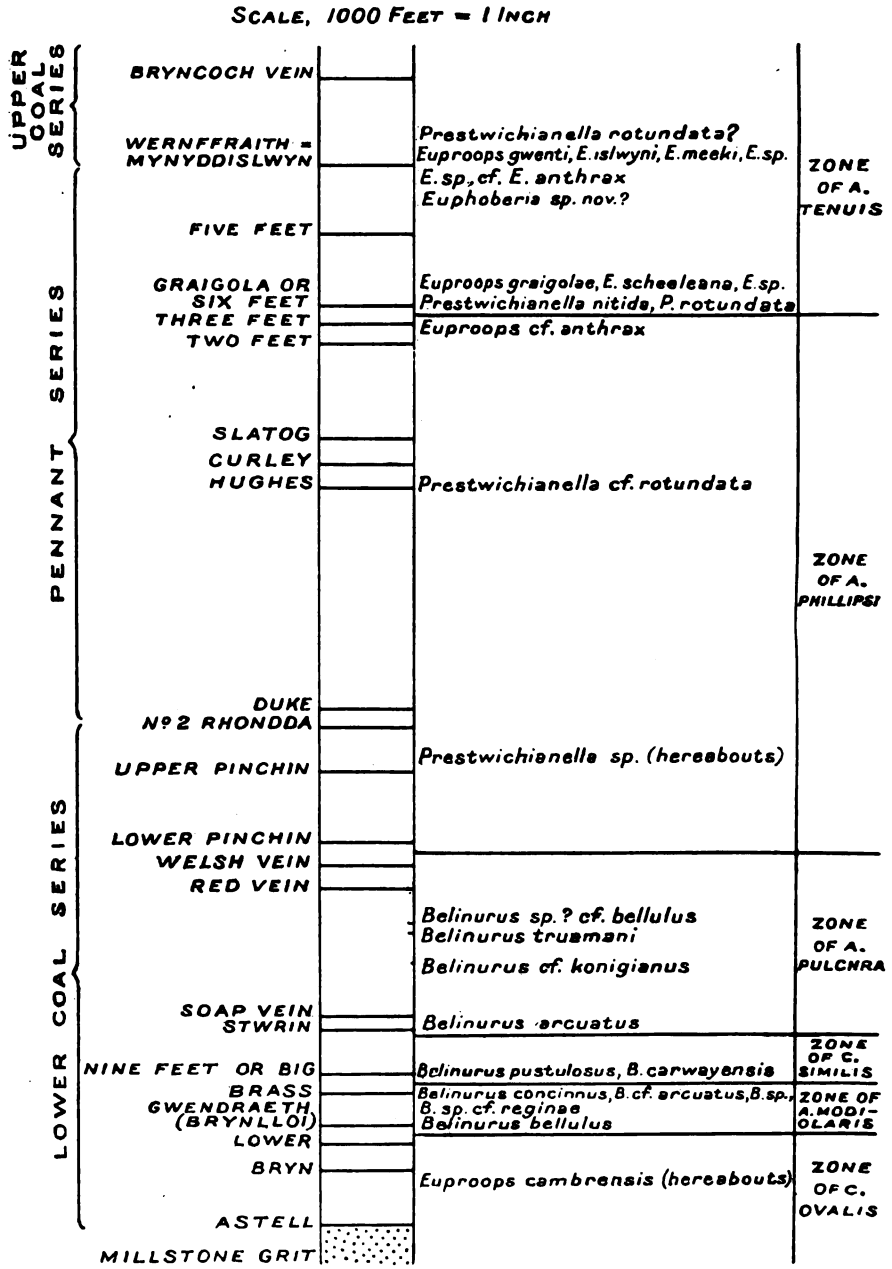

FIG. 16—*Table showing vertical range of* Belinurus, Euproops, *and* Prestwichianella *in South Wales.*

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VII.—'NIPS' AND 'ROCK-RIDERS' IN THE WEST CUMBERLAND COALFIELD

By T. Eastwood, A.R.C.Sc.

Text-figures 1 and 2

Accounts of the Coal Measures, including the sequence and the correlation of the coal seams, of West Cumberland have appeared in previous 'Summaries of Progress.'[1] It may be stated briefly, however, that the Cumberland Coal Measures consist of an upper more or less barren and arenaceous series, styled the Whitehaven Sandstone, and a lower more argillaceous group containing a large number of coal seams, which is referred to as the Productive Measures. This lower group is about 1,000 feet in thickness and the seams usually mined are grouped in the middle 500 feet, the most important—the Main Band—occurring about midway. The principal seams in upward succession are: the Six-quarters, the Little Main, the Yard, the Main Band, the Bannock Band and the Ten-quarters. All have received synonyms in different parts of the area.

In common with other districts the continuity of the coal seams is liable to interruptions from various causes. Some of these may be referred to accidents of deposition owing to inequalities of the platform on which they were laid down; *e.g.*, many of the chance seams were probably deposited in small basins. Other interruptions are due to faulting long subsequent to the formation of the coal. Of these perhaps Cumberland has more than a fair share. There remain, however, certain interruptions which are due to agents operating soon after the formation of any particular seam. Of these the most important are termed 'nips,' while those of lesser importance are 'rock-riders.' In nips the coal is absent 'in plan,' while with rock-riders it is removed 'in elevation.' Both apparently depend on the presence of sandstone not far above the coal.

The nips of West Cumberland are the equivalent of the 'wash-outs,' 'wants,' or 'dumb-faults' that are met with in other coalfields such as Warwickshire and Yorkshire, but in our area the coal is seldom removed along well-defined channels that are referable to stream courses of Coal Measure times. On the other hand, although long narrow nips such as are attributed to stream action do occur, by far the larger area of coal is removed in haphazard fashion, and must be referred, in general, to the action of shifting currents in the deltas bringing down sands which ultimately formed the roof sandstones. Their distribution is shown on the map (Fig. 1).

Nips, as a rule, are first encountered in the top part of a seam and when followed along are found to descend with varying rapidity

[1] For 1921 (1922), 1924 (1925) and 1925 (1926).

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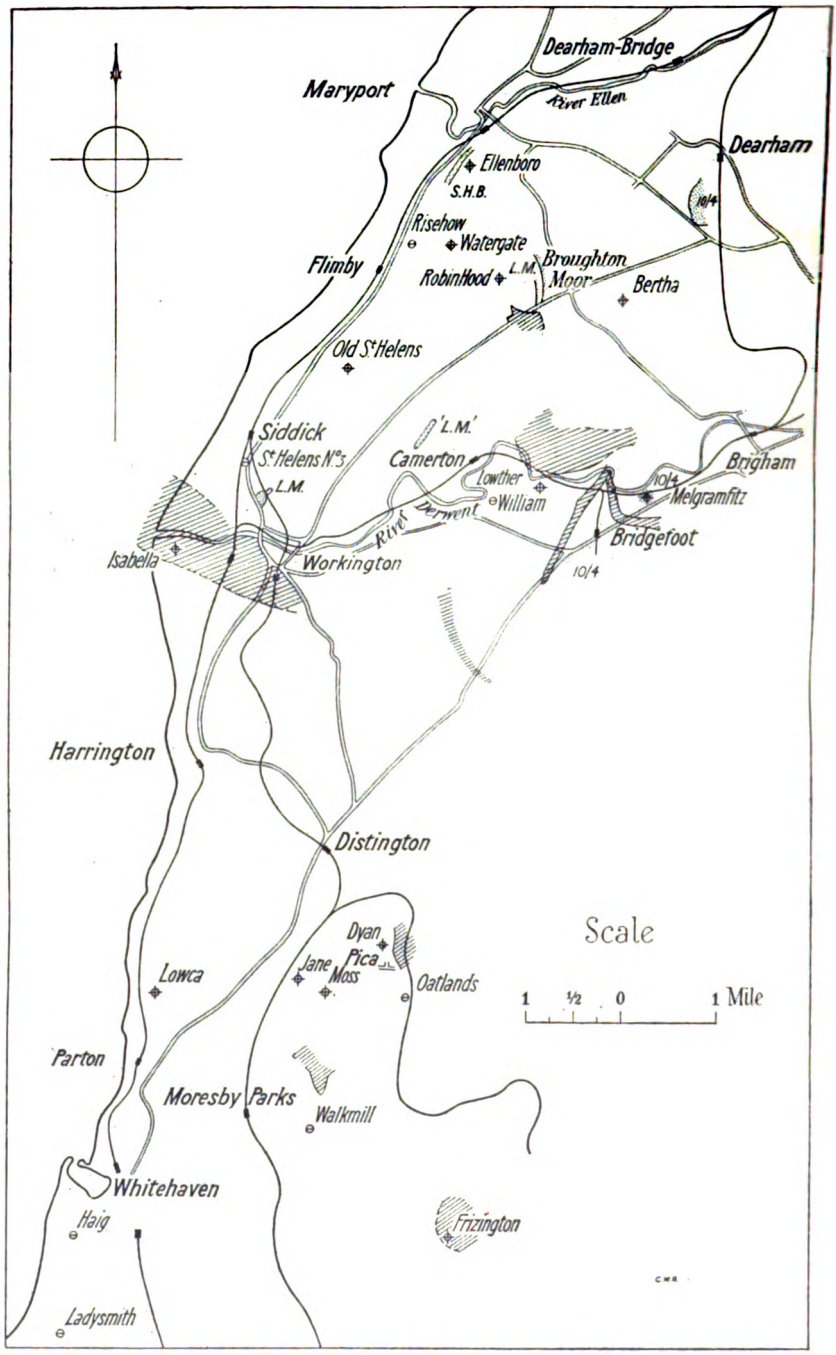

FIG. 1.—*Map showing Distribution of 'Nips' in West Cumberland.* Shaded areas refer to Main Band; stippled areas to other seams. S.H.B. = Senhouse High Band; 10/4 = Ten-quarters Coal; L.M. = Little Main; 'L.M.' = Camerton Little Main.

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until the greater part, or all, of the seam is removed. In some cases, however, within the limits of completely nipped ground, all the coal is not lost. In the Moresby area, for instance (Fig. 2), where

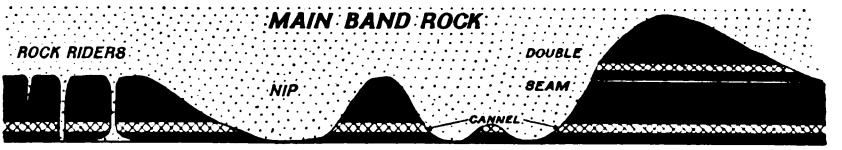

FIG. 2.—*Diagrammatic section of nipped ground in the Main Band, Walk Mill Pit, Moresby.*

Showing rock-riders, partial and complete nips and duplication of the seam.

nipped ground was met with in the Main Band, the seam was repeatedly cut out by the roof sandstone, but irregular 'islands' of coal remained, in some cases the lower part of the seam—including the characteristic band of cannel—being left, in others the entire thickness. Such occurrences may be regarded as more or less normal, but on the edges of some of the nips the seam was duplicated. This repetition was not due to overfolding, for the cannel in every case occurred in the lower part of both seam and duplicate. Furthermore, no crushing or slickensiding, such as one would expect in the event of overthrusting, was observed.

Prof. P. F. Kendall[1] has suggested that the duplication of seams adjacent to nipped areas is due to lurching of the ill-consolidated material under seismic stresses. This is probably true in many instances when 'wants' occur along well-defined lines, but to account for the irregular occurrences at Moresby it is suggested that large masses of coal material were rafted from their bed by strong floods and stranded on other portions which resisted the onslaught of the waters.

Other areas in which the Main Band has been removed include Pica, where a nip was met with east of Dyan Pit. This probably extends for a considerable distance in an easterly direction. To the west, between Pica and Distington, a smaller one occurs around Moss Pit and the seam is thinner than usual at Jane Pit.

Farther east again, at Frizington Colliery, the Main Band is partially nipped to the south-west of the shaft and appears to be entirely wanting for some distance to the north and north-east.

In the ground underlying the Derwent valley large areas of the Main Band have been removed by penecontemporaneous erosion. The nips here belong to two types (1) ill-defined like that at Moresby, and (2) well marked 'wants' of linear character such as are attributed to stream erosion. (It is noteworthy, though the circumstances may be purely fortuitous, that it is in this area that the Main Band begins to split up into the Cannel, Metal and Crow Bands.)

[1] 'On "Wash Outs" in Coal Seams and the effect of Contemporary Earthquakes,' *Abstract Proc. Geol. Soc.*, No. 1031, Jan. 17, 1919, pp. 28-31.

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A large area of the first type occurs near the mouth of the Derwent and is known as the 'Great Nip.' In the shaft of Isabella Pit the coal is absent, but to the south-west the lower part makes its appearance and the seam gradually regains its normal character. The coal is also absent in most of the old pits in the northern part of Workington. Farther north nipped ground was entered in the workings south-west of St. Helens No. 3 Pit, Siddick. If this be continuous with that of Isabella Pit the 'Great Nip' of Workington must be about three-quarters of a mile in breadth and over a mile in length.

On the east side of Workington the Main Band horizon is thrown out by the 'Great Upcast Fault.' Farther east, however, near William Pit, the normal seam is present but is cut out by sandstone towards outcrop south of the William Pit workings. Continuing in an eastward direction we find the nips of Lowther and Melgramfitz pits. Those south of the Derwent are of the second or linear type and may unite as shown on the map (Fig. 1). That north of the river belongs to the first type and at its western end may be more extensive than indicated.

North of the Derwent valley small nips are known in the Main Band at Old St. Helens; they appear to be more extensive (as one would expect) in the upper or Metal Band portion of the seam. A still larger one occurs on Broughton Moor. Sections south of Robin Hood Pit show successive portions of the Cannel Band (here the most important seam) cut out by the freestone roof until the seam is entirely wanting.

Nips do not appear to be so extensive in seams other than the Main Band, but, in addition to smaller occurrences, the following may be noted.

The Little Main, one of the most regular seams in the coalfield, usually has a roof of blue mudstones, but in two of the places where a sandstone roof is locally developed—Siddick and Broughton Moor—nips are present. At Camerton a seam known as the Little Main, but lying between the true Little Main and the Six-quarters, is nipped; and the Ten-quarters is locally cut out by its freestone roof at Melgramfitz, at Bridgefoot, and south-east of Dearham. The Senhouse High Band, a coal occurring in the Whitehaven Sandstone Series, is subject to nips in the Ellenborough workings.

Next to be considered are the narrow, wall-like, more or less vertical ribs of sandstone known as rock-riders. These vary from an inch or less to 2 feet or so in thickness. Their connexion with the roof sandstone was noted in the nipped ground at Moresby. There, as the nips were approached, joints in the coal were enlarged and filled with sandstone identical, and in some cases continuous, with that forming the roof. In some instances the rock not only penetrated the full thickness of the seam but spread out along its floor forming small bars (Fig. 2). In the few instances directly

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observed the bedding in the sandstone forming the ribs was not well defined and the rock split irregularly.

It is evident that at Moresby the infilling took place soon after the deposition of the Main Band Coal and probably accompanied the formation of the nips, *i.e.* rents caused by the rafting of adjacent material were filled with sand carried along by the flood waters, bars or buttresses at the base being made by the rocking of the seam under impact of the flood.

In other cases, however, where ribs are not accompanied by nips or wash-outs, as at Whitehaven, the formation of riders may have been of somewhat later date. In such cases it is necessary to be certain of the age of the infilling material. Dr. A. Gilligan[1] mentions cases at Ladysmith Pit, Whitehaven, where a dyke passes through not only the Main and the Bannock Bands but also the 54 feet of intervening strata. He ascribes the infilling material to the Whitehaven Sandstone. While perhaps not impossible it is somewhat difficult to conceive of a crack of less than ten inches in width persisting and keeping open through the 460 feet of mixed shale and sandstone measures that intervene between the base of the Whitehaven Sandstone Series and the Main Band. In material recently submitted by Mr. T. S. Durham from a rock-rider in the Main Band of Haig Pit, Whitehaven, there is no doubt whatever that we are dealing not with Whitehaven Sandstone but with sandstone of the Productive Measures.

Such riders, however, which are unaccompanied by nips of the Moresby type, may well be due to the infilling of cracks—caused by earthquakes—by unconsolidated sediments, as suggested by Dr. Gilligan.[2]

[1] 'On the Sandstone Dykes or Rock-Riders in the Cumberland Coalfield,' *Abstract Proc. Geol. Soc.*, No. 1031, Jan. 17, 1919, pp. 31-36. See also 'Description of a Group of Dykes, termed Riders, discovered in the Whitehaven Colliery,' by Williamson Peile, *Trans. Nat. Hist. Soc. Northumb. and Durham*, vol. I, 1831, pp, 160-4.

[2] *Op cit.*, p. 32.

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VIII.—The Occurrence of a Rhyolite between the Ordovician and Pre-Cambrian Rocks near Habberley, Shropshire

By Talbot H. Whitehead, M.Sc., A.R.C.Sc.

Text-figures 1 and 2.

Pontesford and Earl's Hills (generally alluded to in geological literature simply as 'Pontesford Hill') form the western limit of a somewhat steep-sided valley through which the Habberley Brook flows from Habberley to Pontesford.

Pontesford Hill is formed of volcanic rocks of pre-Cambrian age (Western Uriconian of Callaway[1]) reinforced by basic intrusions.[2] The wooded eastern side of the valley is occupied by grits and conglomerates belonging to that part of the pre-Cambrian sequence known as the Western Longmyndian (Wentnor Series).[3] The middle part of the valley is underlain by grey shales of Ordovician age. These are probably faulted against the Uriconian rocks of Pontesford Hill; but rest unconformably upon the pre-Cambrian rocks towards the east.

Of the pre-Cambrian rocks of Pontesford Hill it is sufficient for the present purpose to mention that they include lavas and fragmental rocks both of acid and of relatively basic composition. These form a stratified series into which dolerite sills have been intruded.

At and north of the Lyd Hole, where, 300 yards south-east of Earlsdale, the Habberley Brook descends a series of small falls, volcanic rocks similar to those of Pontesford Hill are exposed. These include, at the Lyd Hole itself, a rhyolite, and farther north, basic rocks of which some are pyroclastic. Immediately south of the Lyd Hole the Longmyndian rocks appear to succeed the rhyolite without any break. The junction has been interpreted as a fault[4]; but for reasons into which it is not germane to the present purpose to enter, it is believed that this is improbable. On the other hand it has been supposed that an intrusive relation subsists.[5] This interpretation, even if applicable to the rhyolite, is evidently inadmissible as far as the associated pyroclastic rocks are concerned.

The Longmyndian rocks of the area with which this paper deals consist of grits with two beds of conglomerate. Both grits and conglomerates contain much material of volcanic derivation. The dip is to east-south-east at 60 to 75 degrees, and the thickness

[1] *Quart. Journ. Geol. Soc.*, vol. xxxviii, 1882, p. 119; and vol. xlii, 1886, p. 481.

[2] See Boulton, W. S., 'The Igneous Rocks of Pontesford Hill, Shropshire.' *Quart. Journ. Geol. Soc.*, vol. lx, 1904, p. 450.

[3] Blake, J. F., *Quart. Journ. Geol. Soc.*, vol. lxvi, p. 386; and C. Lapworth in 'Geology in the Field' (*Geol. Assoc. Jubilee Vol.*), 1910, p. 748.

[4] Callaway, C., *op. cit.*, p. 121.

[5] Blake, J. F., *op. cit.*, pp. 402, 403.

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of rock between the ' top ' of the Lyd Hole rhyolite and the ' base ' of the ' higher '[1] conglomerate is estimated as 1,250 feet.

The Ordovician rocks are shown as ' Lingula Flags ' on the Old Series map (Sheet 61) of the Geological Survey. The first published note of their Ordovician (' Lower Caradoc ') age appears to be due to C. Callaway.[2] Collections made during the recent six-inch survey of the area have resulted in the following list,[3] in which the graptolites have been named by Dr. G. L. Elles and the other fossils by Mr. J. Pringle :—

Climacograptus antiquus *Lapw.*, (1), (2), (3).
,, bicornis *Hall*, (3).
,, caudatus *Lapw.*, (1).
? ,, wilsoni *Lapw.*, (2).
Cryptograptus tricornis (*Carr.*), (3).
Diplograptus (Mesograptus) foliaceus *Murch.*, (1).
,, ,, multidens *E. & W.*, (2), (3).
,, (Orthograptus) truncatus *Lapw.*, (2).
,, ,, *var.* intermedius *E. & W.*, (1).
Orthis (Dalmanella) *cf.* testudinaria, *Dalm.*, (1).
Trinucleus concentricus (*Eaton*), (1).

These shales may therefore be regarded as lying near the base of the Caradocian.[4]

The unconformable relation of the Ordovician rocks to the pre-Cambrian is clearly brought out by mapping. East of Radlith Wood they rest upon the ' lower ' of the two conglomerates referred to above (p. 120). Traced south-westward the base passes across rocks ' lower ' in the pre-Cambrian sequence until, in the bank of the Habberley Brook south-east of Earlsdale, it rests upon the volcanic rocks of Uriconian type. Here the conglomeratic basement bed is exposed, overlain by fossiliferous shales (Locality 2 of fossil-list). The actual base is not seen again for over half a mile south of this locality, though indications of the shales can be found at several places. Near Earlsdale the shales dip to north-west at 45 degrees. The basement bed is next exposed 1,290 yards south of Earlsdale (or approximately a mile north-east of Habberley), where a ford across the Habberley Brook is shown on the six-inch map

[1] The expressions ' top,' ' base,' ' higher ' are here used merely in relation to the observed local dip, and without prejudice to the question whether the present order is the original one.

[2] *Op. cit.*, p. 121.

[3] Localities and registered numbers : (1) East bank of Habberley Brook, 500 yds. north of the Lyd Hole ; D. 571–586, T.W. 459–464, 477–480. (2) East bank of Habberley Brook 150 yds. north of the Lyd Hole ; D. 587-602, T.W. 465. (3) West bank of Habberley Brook, 300 yds, west of Oaks Lodge (near " ford ") ; D. 603–623, T. W. 466, 467.

[4] Dr. Elles, in naming the graptolites, added the note that they indicated ' the junction of the Caradocian and Llandeilian (zone of *Mesograptus multidens* and *Climacograptus wilsoni*).' The practice of the Geological Survey has been to place the summit of the Llandeilian somewhat lower, at the base of the zone of *Nemagraptus gracilis*. See ' The Country around Carmarthen ' (*Mem. Geol. Surv.*), 1909, p. 39 ; and ' The Country around Haverfordwest ' (*Mem. Geol. Surv.*), 1914, p. 40.

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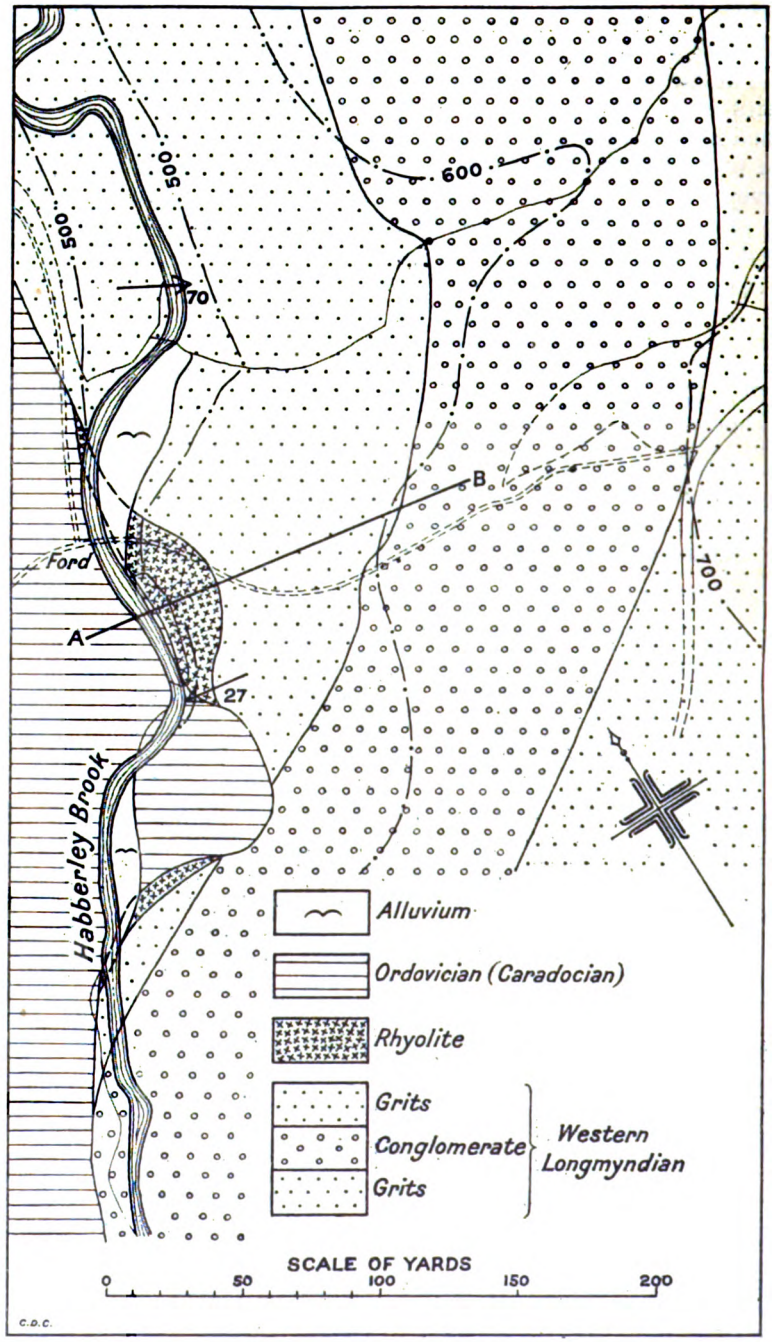

FIG. 1.—*Sketch-map of Habberley Brook, west of Oaks Lodge and about ¾ mile south of Earlsdale.*

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(Shropshire 40 S.E. ; see also Fig. 1). Here the shales which yield fossils (Locality 3 of fossil-list), pass down into sandy beds and these into pebbly grit and conglomerate (Fig. 2). The dip of the sandy beds is to west at 27 degrees. Purple Longmyndian grits are exposed some 50 yards north of the ford. These lie in the ' upper ' half of the beds separating the two Longmyndian conglomerates (see above, p. 120).

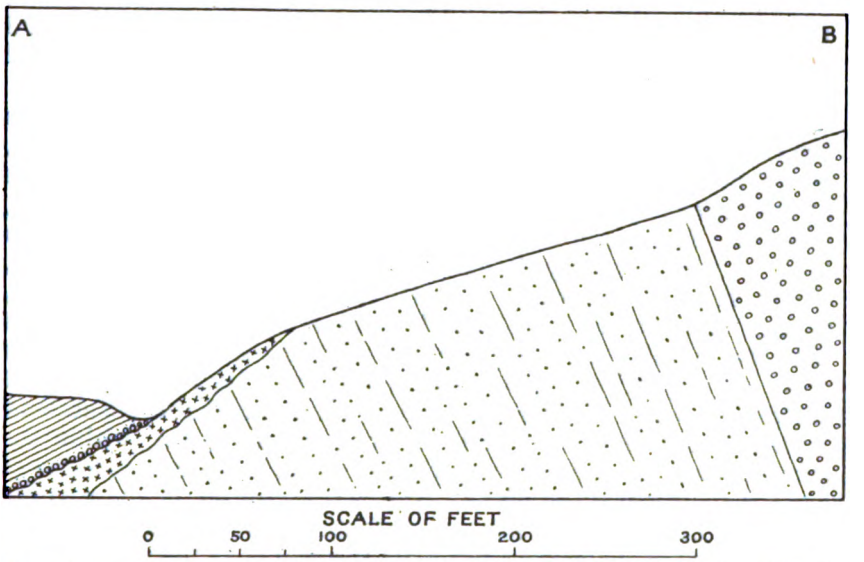

FIG. 2.—*Section across Habberley Brook along the line A-B marked on* FIG. 1.

Where exposed, however, the base of the Ordovician rests, not upon the Longmyndian grits, but upon the rhyolite that is the subject of this paper. This rock has an irregular surface with rounded protuberances that may stand out as much as four feet above the average level. The basal Ordovician conglomerate wraps round these protuberances and is moulded into the hollows between them. The conglomerate contains unmistakable pebbles of the rhyolite in addition to others of quartz and quartzite. Some of the rounded masses of rhyolite, isolated by the conglomerate from the main portion of the rock, may actually be boulders.

The rhyolite is of a dark grey or pinkish colour. The greater part of it shows conspicuous flow-banding. The banding is in places much contorted, but seems to have an average direction not far removed from parallelism with the strike of the Ordovician rocks. The pinkish colour is confined to narrow bands, and it is where these are numerous and close together that the rock, as a whole, assumes that hue. Even narrower white streaks are also to be seen. The microscope[1] shows that the streaked or banded appearance is due to

[1] Slices E. 14344 and E. 14532 in the Survey Collection.

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the alternation (in bands of a millimetre or upwards in thickness) of very fine with relatively coarse aggregates of quartz resulting from devitrification. Streaks of still coarser aggregates probably represent secondary or migrated silica, and are presumably the white streaks seen in hand specimen. Colour differences are probably due principally to the differential distribution of granular or cloudy material, possibly ilmenite, which is more abundant in the coarser bands. Pale chloritic material is more or less evenly distributed. Phenocrysts are rare, and consist of an occasional corroded crystal of what is probably oligoclase, and a few small needle-like crystals of similar composition.

In considering the age of this rhyolite, the possibility that it is pre-Cambrian must be examined. In this connexion it may, firstly, be noted that the rock differs somewhat from the rhyolites of Pontesford Hill and that of the Lyd Hole. The differences, it is true, lie more in the colour and appearance in hand specimen than in the microscopic characters, in which it has, naturally, points in common with the other rhyolites. It is, however, further dissociated from the Lyd Hole rhyolite by the fact that the parts of the Longmyndian sequence with which the two rocks are respectively in contact are separated by about 1,200 feet of strata (p. 121). There is no evidence of faulting that could account for this fact. On the contrary the Longmyndian rocks, within the relevant area, maintain a very regular strike and show no signs of more than trivial dislocations. The actual contact of the rhyolite with the Longmyndian grits is unfortunately nowhere exposed; but the form of its outcrop precludes the idea that the igneous rock is intercalated amongst the pre-Cambrian sediments, either as a flow or as any form of intrusion having a simple relation to their dip and strike. The manner in which the base of the rhyolite mounts the steep eastern bank of the Habberley Brook indicates, in fact, a sheet-like body dipping towards the west and therefore strongly discordant with the pre-Cambrian rocks. It is believed, therefore, that the possibility of its being itself pre-Cambrian may be dismissed; and that it may be regarded as lying unconformably up on the Longmyndian, and, in its turn, unconformably overlain by Caradocian sediments (see Fig. 2).

Volcanic rocks being rare in the Cambrian system the strong presumption is that this rhyolite is of Ordovician age. It has been shown (p. 121) that the upper limit of possible age is low in the Caradocian, or, more precisely, the zones of *Mesograptus multidens* and *Climacograptus wilsoni*, which here appear to be inseparable. It is, therefore, possible that the rhyolite is comparable with some part of the Conway volcanic series, which is overlain by shales belonging to the zone of *Climacograptus peltifer*,[1] or of the lower part of the Snowdon volcanic rocks, which " appear to range from

[1] Elles, G. L., 'The Relation of the Ordovician and Silurian Rocks of Conway (North Wales),' *Quart. Journ. Geol. Soc.*, vol. lxv, 1909, p. 169 (see p. 172).

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the higher part of the zone of *Nemagraptus gracilis* . . . to the zone of *Dicranograptus clingani*."[1] In Shropshire itself, however, the highest Ordovician volcanic rocks lie above the horizon of the shales that rest upon the Habberley Brook rhyolite. The latter is therefore hardly likely to be later in age than the lower volcanic group (the Stapeley Group) of the Shelve area, which rests upon shales with *Didymograptus bifidus*.[2] The Stapeley Group includes lavas, which, however, have the composition of hypersthene or augite andesites.[3]

The grey shales of the valley east of Pontesford Hill represent part of that period of quiet deposition that, in the west of England and Wales, intervened between the Arenig and the Llandeilo-Caradoc outbursts of volcanic activity. In Shropshire this period was one of transgression, and it is interesting to find that the sedimentary transgression was apparently anticipated, perhaps in Arenig times, by a flow of lava.

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[1] Williams, H., 'The Geology of Snowdon (North Wales),' *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927, p. 346 (see p. 391).

[2] Lapworth, C., in 'Summary of Progress' for 1915 (*Mem. Geol. Surv.*), 1916, p. 37.

[3] Watts, W. W., 'The Geology of South Shropshire,' *Proc. Geol. Assoc.*, vol. xxxvi, 1925, p. 341.

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REPORT OF THE GEOLOGICAL SURVEY BOARD FOR 1929

TO THE LORDS OF THE COMMITTEE OF THE PRIVY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

MAY IT PLEASE YOUR LORDSHIPS.—

In accordance with our terms of reference, we, the Geological Survey Board, beg to submit our Tenth Annual Report on the work of the Survey and Museum.

Accommodation (London)

It is with great satisfaction that we are able to report that the excavations preliminary to the construction of the foundations have now been made for the new Offices and Museum at South Kensington.

We regard the site, which is in Exhibition Road midway between the eastern wing of the Natural History Museum and the new buildings of the Science Museum, as in every way an appropriate one.

In view of the unsatisfactory conditions for work in the Jermyn Street Offices and Museum to which we have repeatedly referred since our Fourth Annual Report was presented, we hope that every effort will be made to transfer the Geological Museum and Survey Offices to their new home at South Kensington as early as is possible.

Accommodation (Scottish and Provincial Offices)

The accommodation at Southpark in Edinburgh, the Scottish Headquarters, continues to give satisfaction except in regard to the facilities for the library and for the storage of collections. We trust that the scheme, already submitted, for providing further accommodation by means of an addition to the existing office building may receive sanction during the coming year.

The branch offices at Manchester, Newcastle-on-Tyne, and York are being maintained.

Field Work

The Director's Report for 1929, which is submitted herewith, shows that the stated programme of field work for the year has been carried out.

The Field Units have been engaged on surveys of ten districts as prescribed in the programme approved for the year, viz. :—

Southern District (primary six-inch survey)
Midlands District (primary six-inch survey)

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Yorkshire District (revision of six-inch survey)
Lancashire District (revision of six-inch survey)
Cumbrian District (revision of six-inch survey)
Northumberland and Durham District (revision of six-inch survey)
Ayrshire, Renfrewshire, and Dumbartonshire (revision of six-inch survey)
Fifeshire (revision of six-inch survey)
Orkney Islands (primary six-inch survey)
Shetland Islands (primary six-inch survey)

Details of the work carried out by each of these Field Units are given in the *Summary of Progress* (pp. 46-86).

The maps and memoirs having sold out and new editions being required, attention was also given to the Land's End, Lizard, Torquay, and Merthyr Tydfil areas.

The general standard of the field work done by officers of the Survey has always been high. By 1900 individual members of the staff and individual geologists outside the Survey had produced field survey records of outstanding clearness and accuracy in detail. Their examples have had great influence in raising the standard of geological field records generally. To-day the field work carried out by the officers of the Survey is of very high rank. Recent records on the scale of 6 inches to 1 mile now available for reference and for the preparation of published maps on smaller scales are evidence of the marked efficiency of the Field Staff of the Survey.

Publications

We are pleased to draw attention to the steady output of new publications. The year under review has seen the appearance of one-inch scale coalfield maps of Whitehaven and Wolverhampton in England, and the Hamilton Sheet in Scotland. Six-inch scale quarter sheets numbering nearly sixty and relating to mining areas have also been published. Other one-inch Sheets which have appeared, but which have contained no coalfield work, are the Moreton in Marsh and Stonehaven maps.

Memoirs in explanation of the one-inch scale maps relating to Oswestry, Aldershot, Sudbury, and Moreton in Marsh have been issued. There have also been published:—a Special Mineral Report on 'Ball Clays,' a volume on Attrition Tests of British Road-stones, and a Memoir on the Wells and Springs of Derbyshire.

Inspection of Bores and Shafts

It is pleasing to be able to report that, both in England and in Scotland, the number of borings notified during the year under the provisions of the Mining Industry Act (1926) was considerably larger than in the previous year. The arrangement for such notification is working well. It has resulted in the Survey acquiring

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much information which would otherwise have been lost, and in return the Survey has often been able to render very useful assistance to the mine owners and engineers by identifying the geological horizons passed through.

The provisions of Section 23 of the Mining Industry Act (1926) are, however, limited to sinkings and borings for minerals and do not apply to those for water. As records of borings for water are often of the greatest use to engineers and others when engaged in sinkings for minerals, the Board are of the opinion that early opportunity should be taken to secure for the Survey corresponding information in respect of sinkings and borings for water.

Geophysical Work

We are pleased to report that further substantial progress has been made during the year with the work of testing the value of the Eötvös Gravity Torsion Balance as an aid in the work of the Survey. The third test in the neighbourhood of Portobello, Edinburgh, which was referred to in last year's Report, was completed and a small piece of work was carried out with the same instrument near Thrussington, Melton Mowbray. In the latter case an Eötvös Balance made by Süss of Budapest was also tested. The Süss instrument that was used belongs to the Anglo-Persian Oil Company and was kindly lent to the Survey for the purpose of this test.

One Vertical and one Horizontal Schmidt Magnetometer (Field Balance) were purchased from the Askania Company of Berlin. These were tried out on the well-known Swynnerton dyke in Staffordshire and in the neighbourhood of Melton Mowbray. Accounts of this work are to be published.

Co-operation on Soil Surveys

We are glad to be able to record that during the year assistance to soil experts has been continued. In England, geologists have attended a field meeting near Chippenham (Wiltshire) and a conference on methods of soil surveying held later in London. Soil experts too have accompanied geologists when out mapping in the field. In Scotland, the soil texture edition of One-inch Sheet 22 (Kilmarnock) has been published and work on similar lines is being carried out in the Ayrshire Sheet to the south (One-inch No. 14).

We believe that co-operation in this way will lead to valuable results as it is generally recognized that geological mapping serves as a useful basis for soil surveying.

Collaboration

It is satisfactory on the one hand to record that valuable results continue to be obtained by the occasional employment of geologists outside the Survey who are possessed of special knowledge. Details of these services are given in the Director's Report.

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On the other hand the Survey through individual officers takes part in other public services. Thus, officers serve as representatives on the Local Committees of the Fuel Research Board and maintain close connexion with the developments of research programmes and provide geological information that is helpful to these Committees in their work in carrying on the Physical and Chemical Survey of the National Coal Resources. Another instance of such collaboration is the proposal, mentioned in the Director's Report on p. 18, by the Geological Survey and the Building Research Station to make a joint investigation on building stones both from a geological point of view and from the technological aspect.

Collaboration as outlined above has our entire support.

Membership of Geological Survey Board

In accordance with the arrangements governing the retirement of members of the Geological Survey Board the undermentioned members retire from service on the Board at the end of March, 1930 :—

Sir Francis G. Ogilvie,
Professor T. J. Jehu,
Mr. H. M. Morgans, and
Dr. T. F. Sibly.

Programme of Field Work

The programme of field work for 1930 is :—

(*a*) primary mapping on the six-inch scale in the south-east of England (Reigate, Saffron Walden, and Sevenoaks Sheets), in the Midlands district, in the Shetland Islands, and in Argyllshire (with Inverness-shire) ;

(*b*) revision of original six-inch mapping in the following coalfields and adjacent areas :—Lancashire, Yorkshire, Cumberland, Northumberland, Dumfries-shire, Fifeshire, Renfrewshire, Dumbartonshire, and Stirlingshire ;

(*c*) investigation of underground water-supplies, verification of bore records, examination of mineral resources, and application of geophysical methods of surveying.

F. G. Ogilvie,
Chairman.

31*st March*, 1930.

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SUMMARY OF PROGRESS OF THE GEOLOGICAL SURVEY AND MUSEUM FOR 1929

I. REPORT OF THE DIRECTOR

THE most important event in the history and progress of the Geological Survey of Great Britain during 1929 was the beginning of operations for the building of a new Museum, Library and Offices on the site assigned for that purpose by the Bell Committee in its 1912 Report. The position in Exhibition Road, South Kensington, is ideal for the purpose, being midway between the eastern wing of the Natural History Museum and the new buildings of the Science Museum. With both of these institutions our new Geological Museum is to have direct connexion by means of passages through which the public can travel from one series of galleries to the other. In this way the mineralogical and palaeontological galleries of the British Museum and the mining, metallurgical and geophysical galleries of the Science Museum will be in close juxtaposition with the exhibits of stratigraphical geology and economic geology in the Geological Museum ; and the combined exhibition will provide a display of objects illustrating the composition and history of the earth's crust that has never hitherto been available in any country. That an inception of the building scheme has been made during the past year is a direct consequence of the report and representations of the Royal Commission on National Museums and Galleries which has been sitting in London under the Chairmanship of Viscount D'Abernon during the past three years, and has now completed its task by the publication of its Final Report. The work on the new Geological Museum will take at least three years and as yet only the excavations have been made that are preliminary to the construction of the foundation of the structure. The Architect is Sir Richard Allison of H.M. Office of Works, who was also responsible for the new eastern block of the Science Museum. Although the details of the exterior of the building have not yet been finally settled it is expected that the façade will resemble that of the Science Museum in its essential features. The library and offices of the Geological Survey are to be situated at the back of the new Museum with direct access from the exhibition floors and galleries. A large room is to be provided in the library for students, engineers and others who wish to consult geological maps and literature, and as the library is in close contact with the Science Library the public will find at South Kensington a vast accumulation of periodicals, memoirs and maps on all matters relating to geological science open for immediate reference.

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For many years the Geological Survey has suffered from disabilities of space inherent in the Jermyn Street Museum which was built nearly eighty years ago and was not intended to be wholly occupied by the Survey, as it was originally also the home of the

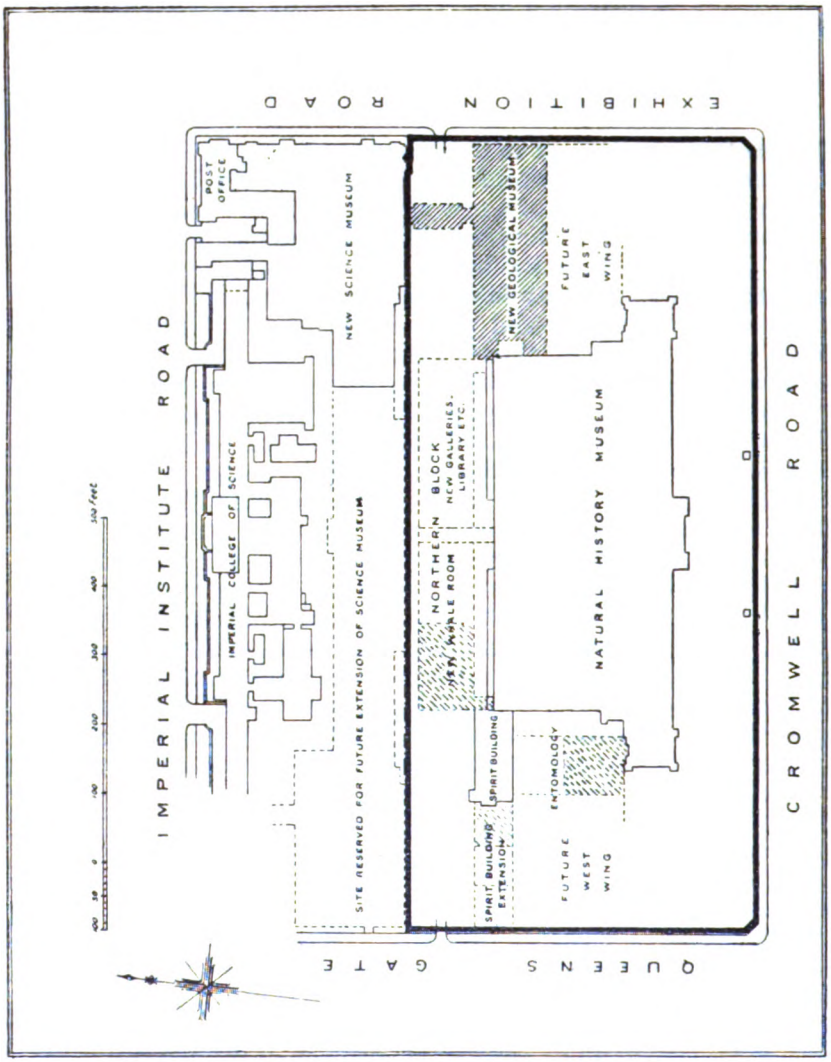

FIG. 1.—*Plan showing the situation of the new Museum of Practical Geology.*
(Taken from Royal Commission on National Museums & Galleries Interim Report, dated 1st September, 1928.)

Royal School of Mines. The new library will provide abundant space for books and maps, of which the Survey has a magnificent collection ; and the new offices and laboratories will greatly facilitate research and publication work by the staff. Recent developments of Survey work have often been much hampered by the impossibility of providing suitable accommodation for the scientific staff, and no

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room has been available for research workers who desired to study the great collections of fossils and rocks in the Museum of Practical Geology. It has been recognized for several years that the Geological Survey has outgrown the accommodation provided in the existing building and under the new conditions both the staff and the public who require to consult the library or the collections will be placed under much more favourable circumstances. The opportunity also of closer collaboration with scientific workers in the adjacent museums at South Kensington is likely to produce results of greater value and more immediate usefulness.

The space occupied by the new Museum is approximately 310 feet long by 105 feet in breadth, facing Exhibition Road. The Museum in Jermyn Street, which at present does not provide accommodation for the whole of the Survey staff, covers an area approximately 12,100 square feet, so that it is less than half as large as the new Museum. The exhibition space contains three galleries similar in their general plan to those of the adjacent new wing of the Science Museum. Of these only two will be open to the public, the uppermost gallery being reserved for study and systematic collections to be consulted especially by research workers. On the ground floor ample space is afforded for exhibits of general geological interest, and the galleries will be devoted to stratigraphy and economic geology. The Survey offices and library, at the back of the new building, occupy about one quarter of the cubic space provided. By this means adequate room will be obtained for the accumulations of geological material for many years, and the reference collections will be in well lighted galleries accessible both to research workers and to the staff. Laboratory accommodation will be ensured for chemical, optical, petrographical, crystallographic, palaeobotanical, geophysical and mineralogical work which has been sorely needed for many years. It is expected also that certain rooms will be available for research workers who wish to investigate the maps and records, or the collections of the Survey.

The detailed plans of the offices and library are now under consideration and the working plans of the whole Museum are being prepared by the architects of H.M. Office of Works. A few figures may be given to indicate the provision of floor space for the different functions which the new building will serve. The total floor space is about 135,000 square feet. Of this the Survey offices with laboratories and library will occupy 40,000. The exhibition space on the main floor and the first and second galleries is 53,000 square feet. The basement provides 25,000 square feet which will be used for storage, workshops and accommodation for subordinate staff. The uppermost gallery, reserved for study collections and research, has a floor space of over 16,000 square feet. Of the total floor space about two-fifths will be allotted to exhibition of specimens and of the remainder about one half will serve as offices, library and laboratories and one half as storage for collections.

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In Scotland also the need for increased accommodation has been pressing for several years. The new offices at Southpark, 19 Grange Terrace, Edinburgh, furnish excellent working rooms for the staff, but the library and collections are much cramped, and part of the rock series is stored in an underground cellar that is not well adapted for permanent occupation. A scheme for providing the required storage by means of an additional building at the side of the offices has been under consideration for the past two years and it is hoped that the Office of Works will have powers to erect this structure during the coming year. Although the Scottish headquarters have been moved out to some distance from the centre of the town it is gratifying to be able to report that the number of enquiries received by letter, telephone and personal visit has not diminished but is showing a steady increase every year. This arises principally from the progress of the revision of the maps of the Scottish coalfields which has brought the staff into touch with all the problems that directly interest the mining industry in the coalfields of Scotland. The Mining Industry Act of 1926 which enacted that all borings for minerals to a depth of over 100 feet should be notified to the Survey has also had a strong influence in making the Survey's work more intimately connected with the operations of mining companies. Every bore of any importance is now inspected and all doubtful problems that arise for discussion receive careful consideration from a skilled and experienced staff of geologists. The results are often of great geological interest as new information that could not possibly be obtained by other means is thus brought to light, and every increase in the knowledge of the structure and sequence of the coalfields is likely to have a practical bearing that directly concerns the mining engineer.

The Survey continues to maintain branch offices at York, Manchester and Newcastle-on-Tyne. In each of these there is a District Geologist in charge, with four geologists and a draughtsman. These branch offices undertake the field work in connexion with the coalfields in which they are situated, and the staff answers all enquiries on the local geology. The geologists also make frequent visits to new borings and shafts which are in progress, and undoubtedly information is obtained in this way that would not be so readily accessible if journeys had to be made from headquarters in London. Owing to the completion of work in the Whitehaven and Maryport coalfields the staff which was located in Whitehaven has been withdrawn and is now in London during the winter season.

FIELD WORK

The energies of the staff during the field season were as usual directed to the progress of mapping in many parts of Great Britain. In this work practically the whole of the geologists were employed for several months. The District Geologists, however, are usually so fully occupied with the task of preparing maps and memoirs for the press and supervising the correction of the proofs for publication

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that their visits to the field are short and are restricted mainly to inspection tours or the examination of critical or disputed sections. Some of the geologists who are engaged in the preparation of maps of important and intricate coalfields have also so much office work to overtake that little time is free for work in the field. The compilation of coalfield maps and memoirs involves an immense amount of study of mining plans, shaft sections and bore records and there is often very little information to be obtained from surface exposures. As the work has to be done to the highest standard of accuracy, since it has important economic relations, it requires prolonged and often very critical research. Some of the coalfields now being surveyed were last mapped more than sixty years ago and much new information has become accessible since the original survey was executed. Even during the course of drawing up the manuscript map new and unexpected facts often come to light that elucidate obscure problems regarding the tectonics. The value of the maps depends entirely on the thoroughness with which the records have been searched; and in general the more information is to hand the more easy it is to attain a definite conception of the true structure of the field. Hence the work, though exacting, cannot be neglected if the purpose which the map is intended to serve is to be adequately fulfilled.

The principal English coalfields in which Survey work was carried on were Yorkshire, Lancashire and Northumberland. In each of these districts there is a branch office which enables the staff to maintain close contact with local developments. Other coalfields in which field staffs were employed are Shrewsbury, Cumberland (Aspatria district), Ayrshire, Lanarkshire (Douglas) and Fifeshire; in these work has been in hand for several years and the survey is nearly finished though the maps and memoirs are not yet published. As will be seen from the list of six-inch coalfield maps issued during the year the work of publication is being actively pushed forward.

As the revision of the British coalfields is making rapid progress it has been possible to devote a considerable amount of time to the re-survey of other districts where economic interests are less directly concerned and where the old maps are now out of date. In Cornwall work has been done in the Land's End and Lizard Sheets, where some maps and memoirs have sold out and new editions are called for. In Devonshire the Torquay map and memoir are under revision. The Reigate Sheet, including parts of Surrey and Kent, is nearly completely re-surveyed and work has been started in the Saffron Walden Sheet. These were originally mapped on the one-inch scale but the revision is being done on the latest six-inch maps. In other districts such as Cumberland, considerable areas of rocks surrounding the coalfields have been revised as entering into the one-inch maps which will ultimately be published.

The principal areas to be surveyed for the first time last year were in the north of Scotland. The original survey of the Orkney Islands has now been finished by Mr. G. V. Wilson assisted by

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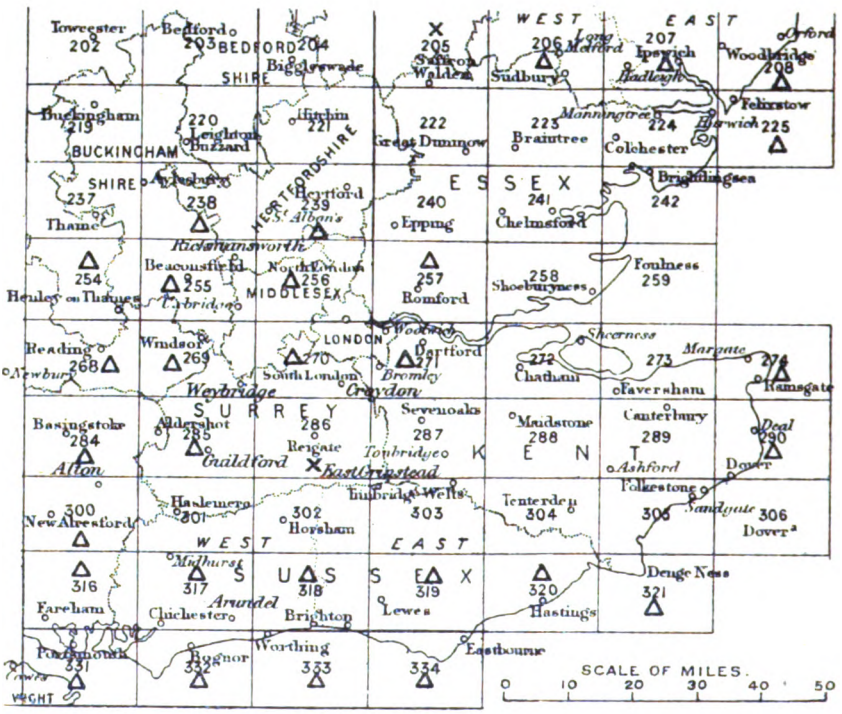
three geologists temporarily lent from the English staff. We have also been able to start the survey of the Shetland Isles, hitherto unmapped, where five geologists of the Scottish staff were employed during three months of the last summer. The geology of these islands is very interesting and varied, and as training ground for the study of metamorphic and intrusive rocks that country could hardly be surpassed. Progress has been slow but this arises from the difficulty and novelty of the ground. With the completion of the Ayrshire and Lanarkshire coalfields during the past summer it is intended to resume work in the West Highlands where it has been discontinued for several years in order to make headway with the coalfields which urgently needed revision.



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△ ,, *Revised, colour-printed, Drift.*

× *Under Revision, 1929.*

FIG. 2.—*Index Map showing One-inch Geological Sheets of the South-east of England.*

General accounts of the field work in the various districts are given in a subsequent part of this volume by the District Geologists who have control of the operations. A few outstanding features, however, may be mentioned in this place. The revision of the maps of the south-east of England has proceeded mainly in the Reigate district and that Sheet was nearly completed at the end of the

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season. Work will be continued there next year and extended into the Sevenoaks Sheet. The revision of the maps of the London area and the outer suburbs of London is now nearly finished, and owing to the dense population and the numerous demands for information about building sites, water schemes and residential conditions the importance of this work can easily be recognized. Towards the end of summer a start was also made with the Saffron Walden Sheet. The geology of this Sheet presents several features of interest and is not free from difficult problems.

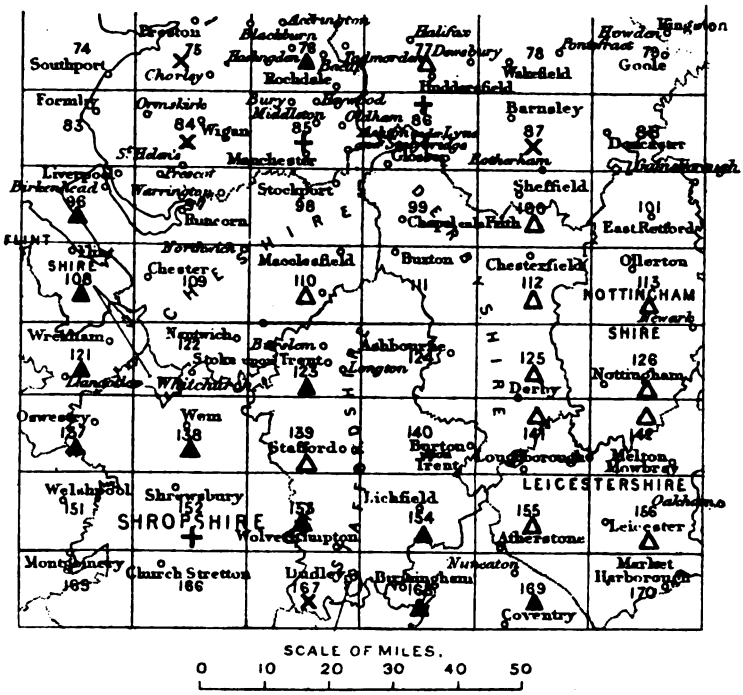

FIG. 3.—*Index Map showing One-inch Geological Sheets of English Midlands.*

In the Midlands district the coalfield revision begun in 1896 is now far advanced. During the past season the Shrewsbury Sheet (152) which includes a small area of coalfield was completed and the maps and memoirs are being prepared for the press. Work was also extended into the Dudley Sheet (167) which is about one-half surveyed. This contains part of the Coalbrookdale coalfield. Both the above-mentioned Sheets are full of geological interest apart from their

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economic importance, and some of the ground is classic in the history of geological research. The pre-Cambrian, Cambrian and Ordovician rocks of the Shrewsbury area though of limited extent are important to geologists and are worthy of very careful and detailed study. Some interesting results have been obtained during the past season and the Shrewsbury map and memoir are being prepared for publication.

In the Lancashire district the staff is still at work on the complicated geology of the Manchester and Wigan coalfields which have been unrevised for over sixty years. Consequently the work though nominally a revision is practically as heavy as if it were an original survey. The number of pits, active and abandoned, is very large, and details of plans, sections and borings are extremely elaborate. The Manchester Sheet (85), however, is finished, the six-inch and one-inch maps published or engraving, and the memoir in hand. The survey of the Wigan Sheet (84) is still not completed and it is hoped that during the coming summer it will approach termination. Meanwhile a little work has been done in the Preston Sheet (75), which however, is a comparatively simple matter, as only about one third of the area represented is occupied by coalfield, and the work already done in adjacent Sheets has familiarised the staff with most of the problems that are likely to arise. The active exertions of the Lancashire and Cheshire Coal Research Association are being supported by the Geological Survey in this district to the utmost of its ability, and the co-operation of chemists, engineers and geologists in this work is proving fruitful of results.

The geological staff working at York branch office has a wide and very important area under its supervision. With the completion of the Huddersfield (77) and Glossop (86) Sheets it has begun the revision of the Barnsley Sheet (87) which contains some of the most important industrial centres in the West Riding. This unit has also the task of keeping in touch with all new information obtained from mines, borings and sinkings in the great Concealed Coalfield of Yorkshire which promises to be one of the greatest sources of coal in Britain. Many enquiries also are being received about water supplies, both for urban and for industrial uses, as there is a large and increasing demand for water from underground sources. Since the geological conditions are comparatively simple it is possible in many cases to give approximate estimates of the probable yield and of the quality of water likely to be obtained.

In Northumberland the energies of the staff have been devoted partly to the active coalfields and partly to the inland tracts where Lower Carboniferous rocks preponderate and coal seams, though present, are not now being exploited on a considerable scale. The revision commenced in the north, at Berwick-on-Tweed, and has now extended southward till it approaches closely to Newcastle. Some valuable areas of productive Coal Measures have been resurveyed but the great coal-bearing area of County Durham has as yet hardly been touched. As the geology of that field is believed

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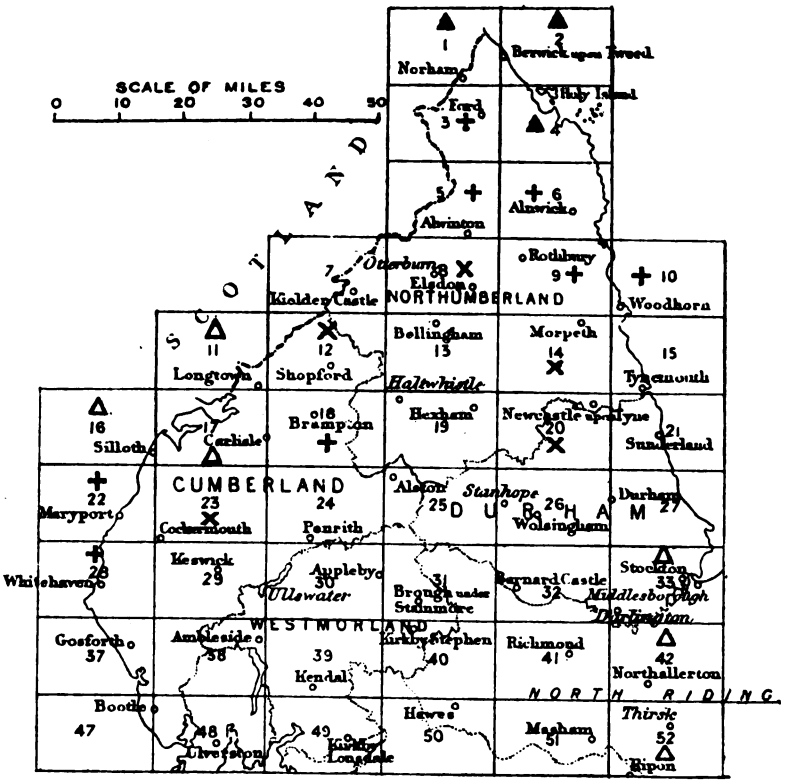
to be simple, and the sequence fairly well understood, this work seemed less urgent than an examination of the northern districts in which coals were known to occur and had been worked on a small scale for many years, though their actual value and importance as future reserves could not be exactly defined. The maps of the English part of the Cheviot Hills are now in hand and the memoirs will be written during the coming winter season.



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▲ ,, *Revised, colour-printed, Solid & Drift.*
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\+ *Revised, not yet published.*
× *Under revision, 1929.*

FIG. 4.—*Index Map showing One-inch Geological Sheets of the North of England.*

The work of revision in Cumberland has reached a stage where it can be definitely stated that most of the productive coal-bearing strata have been re-surveyed and what remains is of comparatively little economic importance. Many points of interest have arisen during the re-survey, as our knowledge of the geology of the Whitehaven (28) and Maryport (22) Sheets was imperfect in many respects, and, owing to the excessive lateral variation of the coal seams

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and associated strata, it has often proved a matter of considerable difficulty to unravel the complicated sequence and trace the correlation of the principal seams from point to point across country. In this field the northern boundary is now reached and is being followed inland. An important problem rises in the possible extension of workable Coal Measures under the red rocks to the north, in the Carlisle basin, and any information bearing on this point has a close connexion with the question of the available coal reserves and future progress of the mining industry in this quarter. South of the coalfield the rocks include Skiddaw Slates and many other characteristic strata of the Lake District which since the days of Sedgwick have been of outstanding interest to English geologists and have been described in many important memoirs. It is expected that in the course of the revision now in progress some interesting results will be gleaned about this fascinating area, which will throw light on its geological history.

In Scotland the Lanarkshire and Ayrshire coalfields are now re-surveyed except for a few outlying areas of no special importance. Work is still going on in the Cumnock district. The six-inch maps are either published or in the press and the important Lanarkshire one-inch map, Sheet 23 (Hamilton), was published in two colour-printed editions (Solid and Drift) during the year. The Alloa and Clackmannan coalfield has been entirely re-surveyed and the work has been carried eastwards through Fife as far as Wemyss. This implies that by far the largest part of that important coalfield has been revised, the part remaining being the Upper Carboniferous around Leven and the small scattered Limestone coalfields of Elie, Ceres, etc., in East Fife which are not now producing coals. The old maps of this field were seriously defective as much work had been done since they were published, and the task of revision has proved very laborious, but every possible assistance has been received from the mining companies. Probably no coalfield in Britain is more broken up by faults; hence it has been necessary to put down very large numbers of bores, and in fact there may be in some districts no less than fifty to the square mile. The importance of the Fife coalfield, however, as a future source of coal is very well known and fully justified the labour that has been spent in compiling the geological information and preparing an authoritative series of six-inch maps.

The completion of the primary survey of the Orkney Islands has proved a comparatively simple task and has proceeded according to plan. Many new points have been brought to notice, more especially the complicated system of faulting that traverses the Mainland and the larger islands. This is much more complicated than was found in the Middle Old Red Sandstone of Caithness. In Orkney also we have a very distinctive series of dykes, which have striking petrological characters. The number of known occurrences has been greatly increased by the careful survey of the archipelago on the six-inch scale. The small but interesting volcanic series

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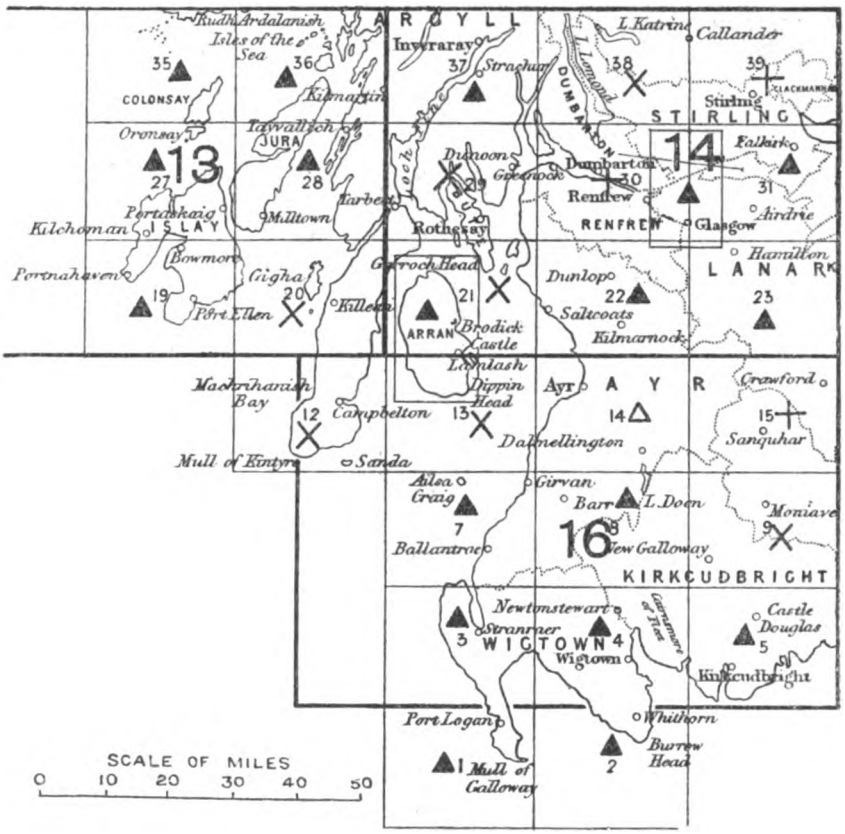

▲ *Published, colour-printed.*
△ *Published, hand-coloured. Revised, colour-printed edition in preparation.*
+ *Published, hand-coloured. Revision in progress.*
X *Published, hand-coloured.*

FIG. 5.—*Index Map showing One-inch Geological Sheets of the South-west of Scotland.*

that lies at the base of the Upper Old Red Sandstone of Hoy, as first remarked by Sir Archibald Geikie, has been mapped out for the first time and its area is considerably greater than was previously believed.

In Shetland some very striking geological phenomena have long been known to exist, and the work done during the past summer has confirmed and extended the conclusions of the geologists who have previously investigated the islands. A remarkable conglomerate has been mapped in Fetlar by Dr. Phemister, and Mr. Haldane has traced a part of the aureole of an extensive granite mass showing intense injection of the country rock by pegmatites and other intrusive veins. Dr. Read's work in Unst shows that the well-known serpentine and gabbro masses have suffered considerably from

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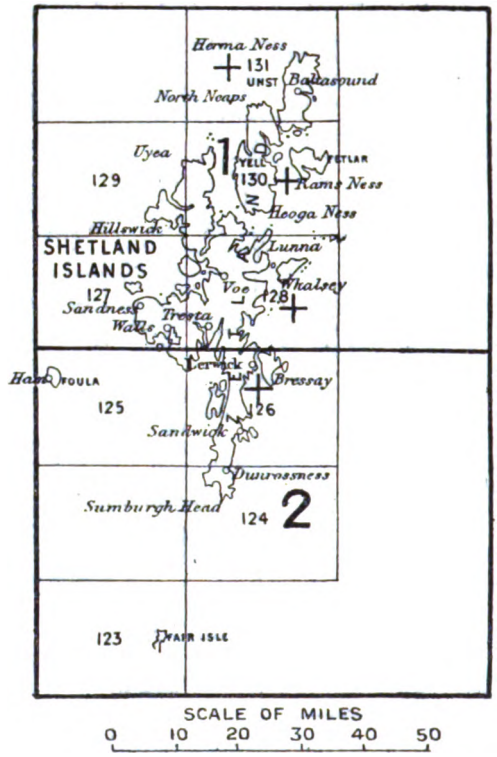
metamorphism although their igneous characters and relations are well preserved.



+ *Field work in progress.*
Maps without symbol unsurveyed.

FIG. 6.—*Index Map showing One-inch Geological Sheets of the Shetland Islands.*

PUBLICATIONS

MAPS

Of the English maps published during the year one is a quarter-inch map of the area surrounding the Bristol Channel. This has not been much altered from the former edition, issued in 1908, as during the intervening period the Survey has not been actively revising that ground. The new map, however, is printed by the latest methods, involving certain changes in the colour scheme, and, though not completely successful, is sufficient to prove that this scheme, which is much simpler than the former one, will be satisfactory when extended to the rest of England.

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Two of the one-inch maps, Chesterfield (112) and Windsor (269) are reprints of maps already published colour-printed in 1913 and 1920, but sold out. In both cases the opportunity has been taken of adopting the latest system of colour-printing and of introducing a few modifications both to the geology and to the colour-scheme. The other one-inch maps published during the year, Whitehaven (Sheet 28) and Wolverhampton (153) are coalfield maps and mark the gradual advance of publication of the revised surveys of English coalfields. Two other Cumberland maps are in the press, Maryport (22) and Brampton (18) and will be published early next year. The Manchester one-inch map (85) is also in the press. All these maps of coalfield areas are now published in two editions, one showing solid rocks only, the other showing also drift. This is in accordance with the recommendations of the Geological Survey Board which found that in some coalfields the productive Carboniferous is so generally covered with drift that its outcrop could be ascertained only with difficulty. An exception has been made in the Huddersfield Sheet (77) as in that country the drift deposits had a very small extension, and hardly obscured the outcrops of the 'solid.'

The number of six-inch English coalfield maps published during the year is 42. Each of them is issued in three states (a) uncoloured, (b) hand-coloured, solid, (c) hand-coloured, drift. This represents a very large amount of painstaking and accurate work, and furnishes a notable contribution to the detailed information about British mineral resources.

In Scotland no quarter-inch map has appeared during the year, though one is in preparation representing the country around Glasgow. The Carrick map (Sheet 8) is based on the revision by Peach and Horne with additional revision of the Carboniferous and parts of the Old Red Sandstone under Mr. E. B. Bailey. The Hamilton map (Sheet 23) represents a very important part of the Lanarkshire coalfield, and the Stonehaven map (Sheet 67) contains much new matter for which we are indebted to Dr. Robert Campbell of Edinburgh University. Fifteen Scottish six-inch coalfield maps have been issued during 1929 and twenty-four are in the press in various stages of engraving. The new series of coalfield maps in Scotland rapidly approaches completion; some are already in second or third editions. As will be seen from the list given on pp. 21-22 our activities so far as publication is concerned are at present principally centred in Fife.

Memoirs

The memoir on Oswestry now published marks the completion of the descriptive accounts of the North Wales coalfield; and this memoir is also noteworthy for the account of the Ordovician and Silurian rocks which that Sheet contains. The survey of that ground was in hand before the outbreak of war and much delay in publication was occasioned by changes of staff and pressure of

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other duties both during the war and subsequently. The completion of this coalfield, however, is a matter for congratulation and brings up to date the publication of the West Midlands and North Wales, an achievement for which we are principally indebted to the industry and judgment of Mr. T. C. Cantrill.

Another important memoir is that on Aldershot and Guildford which contains many important advances in the knowledge of the geology of a district that has long been familiar to London geologists. Professor Boswell's memoir on Sudbury gives an adequate summary of the geology of that Sheet, representing a district with which he is especially familiar,and Mr. Linsdall Richardson's memoir on Moreton in Marsh is rich in new information regarding the Jurassic rocks of a most interesting region that deserves to be better known to geologists. Each of these memoirs is descriptive of a new colour-printed map on the scale of one-inch to one mile.

In Scotland no memoir has been published during 1929 but two very important memoirs, Kilmarnock and Ardnamurchan, are in the press and a memoir on the Alnwick Sheet in Northumberland is also being printed.

Special Reports on Mineral Resources

During the past year one volume has been added to this series, viz.—'Ball Clays' by Dr. Alexander Scott of the Potteries Laboratory, Stoke-on-Trent. This volume contains a full account of the sources, geology, chemistry and economic characters of British pottery clays and should fill a distinct place in the literature of British economic geology.

A volume on British Road-stones has also been issued containing the full reports and statistics of Mr. Lovegrove's tests together with a discussion of the bearing of the petrographical characters of the rocks on their behaviour under the attrition test which Mr. Lovegrove devised.

Towards the close of the year a project was under discussion by which a series of reports on British building stones should be prepared jointly by the Geological Survey and the Building Research Station of the Department of Scientific and Industrial Research. Details have not yet been settled but the proposal is to investigate building stones both from a geological point of view and from the technological aspect. As soon as the field season begins it is intended to send out geological officers to obtain full details of the mode of occurrence of the rocks, their distribution and field characters, and to collect suites of specimens which will be passed to the Building Research Station for intensive investigation.

Water Supply Memoirs

The series of memoirs on the water supply of English counties has been enlarged by the publication of a memoir on Derbyshire.

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Memoirs on Gloucestershire and Worcestershire are in the press and should be published early in the coming year, and one on Leicestershire is in hand. These are all by Mr. L. Richardson, who also wrote the memoirs on Somersetshire and Warwickshire. The collection of records of borings for water goes on without interruption, and many additions are being made to this series every year. In particular the number of borings in and around London seems to increase as many of the large buildings now being erected have private wells. Enquiries on water supply continue to be received in great abundance not only from the south and east of England but also from other districts such as the Midlands, Lancashire and Yorkshire.

The following maps, vertical sections and memoirs were published in 1929 :—

I.—Maps

English and Welsh Maps published in 1929

¼ inch to 1 mile :—

Sheet 18 with part of 17.—Bristol, Cardiff, Crewkerne, Swansea, (1908). *Reprinted, Revised.*

1 inch to 1 mile :—

Sheet 28.—Whitehaven (*Solid*). Original survey by J. C. Ward and R. Russell and published on Old Series maps. Revised by J. G. Goodchild and A. Strahan. Re-surveyed by E. E. L. Dixon, T. Eastwood, S. E. Hollingworth and B. Smith, District Geologist.

Sheet 112.—Chesterfield. Originally published on Old Series maps. Re-surveyed by J. B. Hill, W. Gibson, C. B. Wedd, R. L. Sherlock and G. W. Lamplugh, District Geologist. Published with Drift 1913. *Reprinted with a few additions.*

Sheet 153.—Wolverhampton (*Solid and Drift Editions*). Originally published on Old Series maps. Re-surveyed by T. C. Cantrill, H. Dewey, E. E. L. Dixon, R. W. Pocock, T. Robertson, R. L. Sherlock and T. H. Whitehead ; W. Gibson and T. C. Cantrill, District Geologists.

Sheet 217.—Moreton in Marsh (*Drift Edition*). Originally published on Old Series map. Re-surveyed by H. G. Dines ; H. Dewey, District Geologist.

Sheet 269.—Windsor (*Drift Edition*). Originally published on Old Series maps. Re-surveyed by T. I. Pocock, H. Dewey and C. N. Bromehead ; C. Reid, District Geologist. Published 1920. *Reprinted.*

6 inches to 1 mile (coalfield maps) :—

Cumberland, 13 S.W.—Gilsland. Original survey by D. Burns. Re-surveyed by F. M. Trotter ; B. Smith, District Geologist.

Lancashire, 87 S.E.—Ainsworth. Original survey by E. Hull. Re-surveyed by R. L. Sherlock ; W. B. Wright, District Geologist.

Lancashire, 88 N.E.—Bamford. Original survey by E. Hull. Re-surveyed by W. Lloyd ; W. B. Wright, District Geologist.

Lancashire, 88 S.E.—Heywood. Original survey by E. Hull. Re-surveyed by L. H. Tonks ; W. B. Wright, District Geologist.

Lancashire, 89 N.W.—Rochdale. Original survey by E. Hull. Re-surveyed by D. A. Wray and W. Lloyd ; W. B. Wright, District Geologist.

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Lancashire, 89 S.W.—Shaw. Original survey by E. Hull. Re-surveyed by W. Lloyd; W. B. Wright, District Geologist.

Lancashire, 95 N.E.—Radcliffe. Original survey by E. Hull. Re-surveyed by R. L. Sherlock; W. B. Wright, District Geologist.

Lancashire, 95 S.W.—Walkden. Original survey by E. Hull. Re-surveyed by R. C. B. Jones; W. B. Wright, District Geologist.

Lancashire, 95 S.E.—Clifton. Original survey by E. Hull. Re-surveyed by R. L. Sherlock; W. B. Wright, District Geologist.

Lancashire, 96 N.E.—Middleton. Original survey by E. Hull. Re-surveyed by L. H. Tonks; W. B. Wright, District Geologist.

Lancashire, 96 S.W.—Prestwich. Original survey by E. Hull. Re-surveyed by L. H. Tonks; W. B. Wright, District Geologist.

Lancashire, 96 S.E.—Blackley. Original survey by E. Hull. Re-surveyed by L. H. Tonks; W. B. Wright, District Geologist.

Lancashire, 97 S.W.—Bardsley. Original survey by E. Hull. Re-surveyed by W. Lloyd; W. B. Wright, District Geologist.

Lancashire, 103 N.W.—Boothstown. Original survey by E. Hull. Re-surveyed by R. C. B. Jones; W. B. Wright, District Geologist.

Lancashire, 103 N.E.—Eccles. Original survey by E. Hull. Re-surveyed by R. L. Sherlock; W. B. Wright, District Geologist.

Lancashire, 104 N.W.—Salford. Original survey by E. Hull. Re-surveyed by L. H. Tonks; W. B. Wright, District Geologist.

Lancashire, 104 N.E.—Manchester. Original survey by E. Hull. Re-surveyed by L. H. Tonks; W. B. Wright, District Geologist.

Lancashire, 104 S.W.—Salford. Original survey by E. Hull. Re-surveyed by L. H. Tonks; W. B. Wright, District Geologist.

Lancashire, 104 S.E.—Gorton. Original survey by E. Hull. Re-surveyed by L. H. Tonks; W. B. Wright, District Geologist.

Lancashire, 105 N.W.—Ashton-under-Lyne. Original survey by E. Hull. Re-surveyed by W. Lloyd; W. B. Wright, District Geologist.

Lancashire, 105 S.W.—Audenshaw. Original survey by E. Hull. Re-surveyed by W. Lloyd; W. B. Wright, District Geologist.

Northumberland, N.28 N.E.—Shipleyhill. Original survey by W. Topley. Revised by G. A. Burnett, W. Anderson and R. G. Carruthers, District Geologist.

Northumberland, N.29 N.W.—Rock. Original survey by W. Topley. Revised by G. A. Burnett and R. G. Carruthers, District Geologist.

Northumberland, N.29 S.W.—Denwick. Original survey by W. Gunn and W. Topley. Revised by J. Maden and R. G. Carruthers, District Geologist.

Northumberland, N.29 S.E.—Longhoughton. Original survey by W. Topley. Revised by R. G. Carruthers, District Geologist.

Northumberland, N.33 S.E.—Callaly. Original survey by W. Topley. Revised by W. Anderson; R. G. Carruthers, District Geologist.

Northumberland, N.34 S.W.—Edlingham. Original survey by W. Topley. Revised by W. Anderson; R. G. Carruthers, District Geologist.

Northumberland, N.35 N.W.—Alnwick. Original survey by W. Topley. Revised by C. H. Dinham, J. Maden and R. G. Carruthers, District Geologist.

Northumberland, N.35 N.E.—Lesbury. Original survey by W. Topley. Revised by C. H. Dinham and R. G. Carruthers, District Geologist.

Northumberland, N.35 S.W.—Shilbottle. Original survey by W. Topley. Revised by C. H. Dinham, J. Maden and R. G. Carruthers, District Geologist.

Northumberland, N.42 N.W.—New Moor House. Original survey by W. Topley. Revised by A. Fowler, W. Anderson and J. Maden; R. G. Carruthers, District Geologist.

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Northumberland, N.42 N.E.—Shiel Dyke. Original survey by W. Topley. Revised by A. Fowler and J. Maden; R. G. Carruthers, District Geologist.

Northumberland, N.42 S.E.—Newmoor Hall. Original survey by W. Topley. Revised by A. Fowler; R. G. Carruthers, District Geologist.

Northumberland, N.43 N.E.—Warkworth. Original survey by W. Topley. Revised by A. Fowler, J. Maden and R. G. Carruthers, District Geologist.

Northumberland, N.43 S.W.—Swarland. Original survey by W. Topley. Revised by A. Fowler; R. G. Carruthers, District Geologist.

Northumberland, N.88 N.E.—Thirlwall. Original survey by D. Burns, E. J. Hebert and J. C. Ward. Re-surveyed by F. M. Trotter; B. Smith, District Geologist.

Northumberland, N.97 (S.W. & S.E.)—Hartleyburn Common. Original survey by D. Burns. Re-surveyed by F. M. Trotter and S. E. Hollingworth; B. Smith, District Geologist.

Shropshire, 19 N.W.—Morda. Surveyed by C. B. Wedd; T. C. Cantrill, District Geologist.

Shropshire, 36 N.E.—Donnington. Surveyed by T. H. Whitehead; T. C. Cantrill, District Geologist.

Shropshire, 43 S.E.—Madeley. Surveyed by R. W. Pocock; T. C. Cantrill, District Geologist.

Staffordshire, 62 N.E.—Wednesfield. Surveyed by W. Gibson and T. Robertson; T. C. Cantrill, District Geologist.

Yorkshire, 273 N.W.—Birds Edge. Original survey by J. C. Ward, J. R. Dakyns and A. H. Green. Re-surveyed by C. N. Bromehead, District Geologist.

Scottish Maps published in 1929

1 inch to 1 mile :—

Sheet 8.—Carrick. Original survey in 1893. Revised by B. N. Peach, J. Horne, J. E. Richey, V. A. Eyles, J. B. Simpson, A. G. MacGregor and G. V. Wilson; E. B. Bailey, District Geologist.

Sheet 22.—Kilmarnock (*Soil Texture Map*). Surveyed by R. A. Berry, C. Louden, E. M. Melville and I. B. Mowat of the West of Scotland Agricultural College.

Sheet 23.—Hamilton (*Solid and Drift Editions*). Original survey in 1872. Revised by B. N. Peach, C. T. Clough, L. W. Hinxman, J. S. Grant Wilson, E. M. Anderson, R. G. Carruthers, M. Macgregor, B. Lightfoot, C. H. Dinham, J. E. Richey, G. V. Wilson, H. H. Read, G. Ross, A. G. MacGregor and J. Phemister.

Sheet 67.—Stonehaven. Original survey by D. R. Irvine. Revised by G. Barrow. Further revision by R. Campbell.

6 inches to 1 mile (coalfield maps) :—

Ayrshire, 46 N.E.—Benquhat. Original survey by J. Geikie. Revised by J. B. Simpson; E. B. Bailey, District Geologist.

Ayrshire, 46 S.E.—Dalmellington. Original survey by J. Geikie. Revised by J. B. Simpson; E. B. Bailey, District Geologist.

Ayrshire, 47 N.W.—Upper Beoch, N.E. of Dalmellington. Original survey by B. N. Peach. Revised by J. B. Simpson; E. B. Bailey, District Geologist.

Ayrshire, 47 S.W.—Benbrack, E. of Dalmellington. Original survey by B. N. Peach. Revised by B. N. Peach, J. Horne and J. B. Simpson; E. B. Bailey, District Geologist.

Ayrshire, 50 S.W.—Old Dailly. Original survey by A. Geikie. Revised by B. N. Peach, J. Horne, J. E. Richey and J. B. Simpson; E. B. Bailey, District Geologist.

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Fifeshire, 32 S.E.—Bogside Station. Original survey by B. N. Peach. Revised by D. Haldane; C. H. Dinham, District Geologist.

Fifeshire, 35 N.E.—Chapel. Original survey by H. H. Howell. Revised by J. Knox; C. H. Dinham, District Geologist.

Fifeshire (35 S.E. & 36 S.W.).—Kirkcaldy. Original survey by H. H. Howell and A. Geikie. Revised by J. Knox; C. H. Dinham, District Geologist.

Fifeshire, 37 N.E.—Tulliallan Forest. Original survey by B. N. Peach. Revised by D. Haldane; C. H. Dinham, District Geologist.

Fifeshire, 39 N.W.—Dunfermline (E. Part). Original survey by A. Geikie. Revised by D. Haldane, J. K. Allan and C. H. Dinham, District Geologist.

Lanarkshire, 3 S.E.—Greengairs, Longriggend. Original survey by J. Geikie and B. N. Peach. Revised by R. G. Carruthers and E. M. Anderson. *New Edition* with additional information.

Lanarkshire, 19 N.W.—Morningside. Original survey by J. Geikie. Revised by L. W. Hinxman and M. Macgregor.

Lanarkshire, 32 S.W.—Broken Cross Muir. Original survey by A. Geikie and B. N. Peach. Revised by L. W. Hinxman and G. Ross; M. Macgregor, District Geologist.

Lanarkshire, 32 S.E.—Sandilands, Ponfeigh Station. Original survey by A. Geikie and B. N. Peach. Revised by L. W. Hinxman, H. H. Read and G. Ross; M. Macgregor, District Geologist.

Stirlingshire, 18 S.E.—Dunmore, Airth. Original survey by B. N. Peach. Revised by C. H. Dinham, District Geologist.

Manuscript copies of the following maps on the scale of six inches to one mile were deposited in the Library for public reference. They are not to be published. The English maps are deposited in the head office in London. These manuscript copies of unpublished maps may be examined in the Library of the Geological Survey on week days from 10 a.m. to 5 p.m. Copies of them may be obtained at the cost of drawing which will be quoted on application to the Superintendent of Maps. Photographs of these maps will also be supplied, on the scale of 3 inches to one mile approximately, at the cost of 2*s*.6*d*. to 3*s*. 6*d*. per quarter sheet.

The Scottish manuscript copies which are deposited in the office at 19, Grange Terrace, Edinburgh may on application be forwarded to the London Office for consultation.

English Manuscript Maps deposited for reference

Berkshire, 1 N.E. (Oxford, 32 N.E.), S.E. (Oxford, 32 S.E.); 2 N.W. (Oxford, 33 N.W.), S.W. (Oxford, 33 S.W.); 5 N.E. (Oxford, 38 N.E.), S.W. (Oxford, 38 S.W.), S.E. (Oxford, 38 S.E.); 6 N.W. (Oxford, 39 N.W.), N.E. (Oxford, 39 N.E.), S.W., S.E. (Oxford, 39 S.E.); 10 N.W. (Oxford, 45 N.W.), N.E. (Oxford, 45 N.E.), S.W. (part) (Oxford, 45 S.W.), S.E. (part) (Oxford, 45 S.E.); 16 N.W. (Oxford, 49 N.W.), N.E. (Oxford, 49 N.E.), S.E. (Oxford, 49 S.E.); 22 N.W. (Oxford, 52 N.W.), N.E. (Oxford, 52 N.E.), S.W. (Oxford, 52 S.W.); 25 N.W. (Wilts., 24 N.W.), N.E., S.W. (Wilts., 24 S.W.), S.E.; 29 N.W. (Oxford, 56 N.W.), N.E. (Oxford, 56 N.E.), S.W. (Oxford, 56 S.W.), S.E. (Oxford, 56 S.E.); 30 N.W. (Oxford, 57 N.W.); 33 N.W. (Wilts., 30 N.W.), N.E. (Wilts., 30 N.E.), S.W. (Wilts., 30 S.W.), S.E. (Wilts., 30 S.E.); 41A N.E. (Hants., 7 N.E.; Wilts., 43 N.E.).

Buckinghamshire, 18 N.E. (Oxford, 18 N.E.), S.E.; 36 N.W. (part) (Oxford, 41 N.W.); 40 N.E. (Oxford, 47 N.E.), S.E. (Oxford, 47 S.E.); 50 N.E. (Oxford, 53 N.E.).

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Cheshire, 3 S.E.
Cumberland, 11 S.W., S.E.; 12 S.W., S.E.; 13 N.W.; 17 N.W., N.E., S.W., S.E.; 18 N.W.; 24 N.W., N.E., S.W., S.E.; 25 N.W., S.W., S.E.; 26 N.W., S.W.; 31 N.W., N.E.; 32 N.W., N.E.; 33 N.W.; 54 N.E.; 62 N.E., S.E.; 68 N.E., S.E.; 73 N.W., N.E.
Dorsetshire, 9 S.E.
Hampshire, 7 S.E. (Wilts., 43 S.E.); 14 S.W. (Wilts., 48 S.W.), S.E. (Wilts., 48 S.E.); 15 N.E. (Wilts., 49 N.E.), S.W. (Wilts., 49 S.W.), S.E. (Wilts., 49 S.E.); 22 N.W. (Wilts., 55 N.W.), N.E., S.W. (Wilts., 55 S.W.), S.E. (Wilts., 55 S.E.); 23 N.W., N.E., S.W., S.E.; 24 N.W., N.E., S.W., S.E.; 25 N.W., N.E., S.W., S.E.; 30 N.E. (Wilts., 61 N.E.), S.E. (Wilts., 61 S.E.); 31 N.W., N.E., S.W., S.E.; 32 N.W., N.E., S.W., S.E.; 33 N.W., N.E., S.W., S.E.; 38 N.E. (Wilts., 67 N.E.), S.E. (Wilts., 67 S.E.); 39 N.W., N.E., S.W., S.E.; 40 N.W., N.E., S.W., S.E.; 41 N.W., N.E., S.W., S.E.; 46 S.W. (Wilts., 71 S.W.); 46A S.E. (Wilts., 70 S.E.); 47 N.E. (Wilts., 72 N.E.), S.E. (Wilts., 72 S.E.); 54A N.W. (Wilts., 75 N.W.), N.E. (Wilts., 75 N.E.), S.E.; 55 N.W. (Wilts., 77 N.W.), N.E. (Wilts., 77 N.E.), S.W. (Wilts., 77 S.W.), S.E. (Wilts., 77 S.E.); 75 N.W., N.E., S.W., S.E.; 84 N.W., N.E., S.W., S.E.
Oxfordshire, 26 N.W. (part), N.E. (part), S.W., S.E.; 27 N.W. (part), S.W., S.E.; 32 N.W., S.W.; 33 N.E., S.E.; 34 N.W., S.W.; 38 N.W.; 40 N.W., N.E., S.W., S.E.; 41 S.W. (part); 46 N.W., N.E., S.W., S.E.; 47 N.W., S.W.; 50 N.W., S.W.; 52 S.E.; 53 N.W., S.W., S.E.
Sussex, 47 S.W.; 60 N.W., S.W.
Wiltshire, 40 N.E., S.W., S.E.; 41 N.W., N.E., S.W., S.E.; 42 N.W., N.E., S.W., S.E.; 43 N.W., S.W.; 45 N.W., N.E., S.W., S.E.; 46 N.W., N.E., S.W., S.E.; 47 N.W., N.E., S.W., S.E.; 48 N.W., N.E.; 49 N.W.; 52 N.W., N.E., S.W., S.E.; 53 N.W., N.E., S.W., S.E.; 54 N.W., N.E., S.W., S.E.; 58 N.W., N.E., S.W., S.E.; 59 N.W., N.E., S.W., S.E.; 60 N.W., N.E., S.W., S.E.; 61 N.W., S.W.; 63 N.E. (part), S.E. (part); 64 N.W., N.E., S.W., S.E.; 65 N.W., N.E., S.W., S.E.; 66 N.W., N.E., S.W., S.E.; 67 N.W., S.W.; 69 N.W., N.E., S.W., S.E.; 70 N.W., N.E., S.W.; 71 N.W., N.E., S.E.; 72 N.W., S.W.; (74 N.W. and 74A N.E.); 74 N.E., S.W., S.E.
Yorkshire, 230 N.E.; 271 N.W., N.E.

Scottish Manuscript Maps deposited for reference

Argyllshire (Mull), 38; 38A N.E., S.E.; 68; 107; 108; 119 N.W., N.E.; 120 N.W., N.E.
Ayrshire, 39 S.E.; 46 S.W.; 52 N.W.
Berwickshire, 1 S.W., S.E.; 2 S.W., S.E.; 3 N.E., S.W., S.E.; 4; 5; 6; 11; 12 N.W., S.W., S.E.; 18; 26; 30.
Edinburgh (Midlothian), 19.
Fifeshire, 39 S.W.; 42 N.E.; 43 N.W.
Haddington (East Lothian), 11; 15; 16; 17 N.W., N.E., S.W.; 18; 19; 20 N.W., N.E., S.W.; 21 N.W.
Lanarkshire, 19 S.E.

List of Maps in the press at the close of 1929

English Maps in the press

¼ inch to 1 mile :—

Sheet 9 with 10.—Barmouth, Chester, Holyhead, Shrewsbury. (*Solid edition*). *Reprinting.*

1 inch to 1 mile :—

Sheet 6.—Alnwick (*Solid and Drift Editions*).

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Sheet 18.—Brampton (*Solid and Drift Editions*).
Sheet 22.—Maryport (*Solid and Drift Editions*).
Sheet 28.—Whitehaven (*Drift Edition*).
Sheet 85.—Manchester (*Solid and Drift Editions*).

6 inches to 1 mile (coalfield maps) :—

Derbyshire, 2 S.E.
Lancashire, 97 N.W.
Northumberland, N 52 S.W. ; N 58 N.E., S.E. ; N 59 N.W. ; N 88 S.E. ; N 97 N.E.
Shropshire, 36 S.E. ; 43 N.E.
Yorkshire, 261 S.W. ; 272 N.E., S.E. ; 273 S.W. ; 281 N.W.

Scottish Maps in the press

1 inch to 1 mile :—

Sheet 32.—Edinburgh (*Solid Edition*).
Sheet 108.—Altnaharra.
Sheet 109.—Achentoul.

6 inches to 1 mile (coalfield maps) :—

Ayrshire, 41 S.E. ; 52 N.E.
Fifeshire, 27 S.E. ; 28 S.W. ; 33 N.E., S.W., S.E. ; 34 S.W. ; 35 N.W. ; 36 N.W. ; 37 S.E. ; 38 N.W., N.E., S.W., S.E.
Fifeshire and Kinross-shire, 26 S.W., S.E. ; 33 N.W. ; 34 N.W.
Kinross-shire, 24 S.E.
Lanarkshire, 7 N.W. (*Reprint*) ; 38 N.W., N.E.
Stirlingshire, 18A S.W. with 25 N.W.

II.—Vertical Sections of Strata

English Vertical Sections published in 1929

Sheet 83.—Sections of Shafts in and below the Pennant Grit in the Taff, Aberdare and Rhondda Fach Valleys. Scale 100 feet to an inch. (*Reprint*).
Sheet 85.—Sections of Shafts, etc., in the Tawe, Dulais, Neath, Avan, Llynfi, Garw and Ogmore Valleys. Scale 100 feet to an inch. (*Reprint*).

English Vertical Sections in the press at the close of 1929

Sheet 93.—Sections of Shafts in the Coal Measures of the Abergavenny District (Sheet No. 232) of the South Wales Coalfield, being supplementary to Vertical Sections, Sheet 81. Compiled by T. Robertson.
Sheet 94.—Sections of Shafts and Borings in the Southern Part of the South Staffordshire Coalfield. Compiled by Talbot H. Whitehead.

Scottish Vertical Sections in the press at the close of 1929

Sheet 16.—Vertical Sections illustrating the Ayrshire Coalfields (Area III), Prestwick, Mauchline, Cumnock and Muirkirk Districts.

III.—Memoirs

The following list shows the memoirs published during the year 1929. The work done on them has been mainly the correction of proofs and preparation of indexes.

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English Memoirs published in 1929

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for the year 1928 :—
Part I.—With Report of the Geological Survey Board and Report of the Director. 99 pp. ; 6 text-figures. 1929. Price 2*s.* ***net.***
Part II.—128 pp. ; 3 plates ; 37 text-figures. 1929. Price 3*s.* ***net.***

Attrition Tests of British Road-stones. By E. J. Lovegrove, M.Inst. C.E., with notes by J. Allen Howe, O.B.E., B.Sc., and Sir John Flett, K.B.E., F.R.S. 84 pp. ; 5 plates. 1929. Price 3*s.* ***net.***

Special Reports on the Mineral Resources of Great Britain. Vol. XXXI.—Ball Clays. By Alex. Scott, M.A., D.Sc., F.R.S.E. 73 pp. ; 7 text-figures. 1929. Price 2*s.* 6*d.* ***net.***

Wells and Springs of Derbyshire. By J. V. Stephens, B.Eng., B.Sc. 155 pp. ; 5 text-figures. 1929. Price 4*s.* ***net.***

The Country around Oswestry. (Explanation of one-inch Sheet 137 : England and Wales). By C. B. Wedd, B.A., B. Smith, M.A., Sc.D., W. B. R. King, M.A., and D. A. Wray, M.Sc., Ph.D., with contributions by T. C. Cantrill, B.Sc., and H. H. Thomas, M.A., Sc.D., F.R.S. 234 pp. ; 4 plates ; 14 text-figures. 1929. Price 5*s.* 6*d.* ***net.***

The Geology of the Country around Sudbury (Suffolk). (Explanation of one-inch Sheet 206 : England and Wales). By P. G. H. Boswell, O.B.E., D.Sc., Professor of Geology in the University of Liverpool. 74 pp. ; 2 plates ; 17 text-figures. 1929. Price 2*s.* ***net.***

The Country around Moreton in Marsh. (Explanation of one-inch Sheet 217 : England and Wales). By Linsdall Richardson, F.R.S.E., with contributions by A. E. Trueman, D.Sc., Daisy M. Williams, M.Sc., R. C. Gaut, M.Sc., and H. G. Dines, A.R.S.M. 162 pp. ; 6 plates ; 9 text-figures. 1929. Price 4*s.* 6*d.* ***net.***

The Geology of the Country around Aldershot and Guildford. (Explanation of one-inch Sheet 285 : England and Wales). By H. G. Dines, A.R.S.M., A.M.Inst.C.E., and F. H. Edmunds, M.A. Palaeontology by C. P. Chatwin, M.Sc. 182 pp. ; 5 plates ; 11 text-figures. 1929. Price 4*s.* 6*d.* ***net.***

Scottish Memoirs published in 1929

Summary of Progress.—See above.

English Memoirs in the press at the close of 1929

Wells and Springs of Gloucestershire.

Wells and Springs of Worcestershire.

The Geology of the Alnwick District. (Explanation of one-inch Sheet 6 : England and Wales).

The Geology of the Maryport District. (Explanation of one-inch Sheet 22 : England and Wales).

The Geology of the Country around Huddersfield and Halifax. (Explanation of one-inch Sheet 77 : England and Wales).

Scottish Memoirs in the press at the close of 1929

The Geology of North Ayrshire. (Explanation of one-inch Sheet 22 : Scotland).

The Geology of Ardnamurchan, North-west Mull and Coll. (Explanation of one-inch Sheet 51 and part of Sheet 52 : Scotland).

Geophysical Work

At the close of 1928 Drs. McLintock and Phemister were engaged on the gravitational survey of the Portobello fault which forms the

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Sheet 18.—Brampton (*Solid and Drift Editions*).
Sheet 22.—Maryport (*Solid and Drift Editions*).
Sheet 28.—Whitehaven (*Drift Edition*).
Sheet 85.—Manchester (*Solid and Drift Editions*).

6 inches to 1 mile (coalfield maps) :—

Derbyshire, 2 S.E.
Lancashire, 97 N.W.
Northumberland, N 52 S.W.; N 58 N.E., S.E.; N 59 N.W.; N 88 S.E.; N 97 N.E.
Shropshire, 36 S.E.; 43 N.E.
Yorkshire, 261 S.W.; 272 N.E., S.E.; 273 S.W.; 281 N.W.

Scottish Maps in the press

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Sheet 32.—Edinburgh (*Solid Edition*).
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Sheet 109.—Achentoul.

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Ayrshire, 41 S.E.; 52 N.E.
Fifeshire, 27 S.E.; 28 S.W.; 33 N.E., S.W., S.E.; 34 S.W.; 35 N.W.; 36 N.W.; 37 S.E.; 38 N.W., N.E., S.W., S.E.
Fifeshire and Kinross-shire, 26 S.W., S.E.; 33 N.W.; 34 N.W.
Kinross-shire, 24 S.E.
Lanarkshire, 7 N.W. (*Reprint*); 38 N.W., N.E.
Stirlingshire, 18A S.W. with 25 N.W.

II.—Vertical Sections of Strata

English Vertical Sections published in 1929

Sheet 83.—Sections of Shafts in and below the Pennant Grit in the Taff, Aberdare and Rhondda Fach Valleys. Scale 100 feet to an inch. (*Reprint*).
Sheet 85.—Sections of Shafts, etc., in the Tawe, Dulais, Neath, Avan, Llynfi, Garw and Ogmore Valleys. Scale 100 feet to an inch. (*Reprint*).

English Vertical Sections in the press at the close of 1929

Sheet 93.—Sections of Shafts in the Coal Measures of the Abergavenny District (Sheet No. 232) of the South Wales Coalfield, being supplementary to Vertical Sections, Sheet 81. Compiled by T. Robertson.
Sheet 94.—Sections of Shafts and Borings in the Southern Part of the South Staffordshire Coalfield. Compiled by Talbot H. Whitehead.

Scottish Vertical Sections in the press at the close of 1929

Sheet 16.—Vertical Sections illustrating the Ayrshire Coalfields (Area III), Prestwick, Mauchline, Cumnock and Muirkirk Districts.

III.—Memoirs

The following list shows the memoirs published during the year 1929. The work done on them has been mainly the correction of proofs and preparation of indexes.

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English Memoirs published in 1929

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for the year 1928 :—
Part I.—With Report of the Geological Survey Board and Report of the Director. 99 pp. ; 6 text-figures. 1929. Price 2*s.* ***net.***
Part II.—128 pp. ; 3 plates ; 37 text-figures. 1929. Price 3*s.* ***net.***

Attrition Tests of British Road-stones. By E. J. Lovegrove, M.Inst. C.E., with notes by J. Allen Howe, O.B.E., B.Sc., and Sir John Flett, K.B.E., F.R.S. 84 pp. ; 5 plates. 1929. Price 3*s.* ***net.***

Special Reports on the Mineral Resources of Great Britain. Vol. XXXI.—Ball Clays. By Alex. Scott, M.A., D.Sc., F.R.S.E. 73 pp. ; 7 text-figures. 1929. Price 2*s.* 6*d.* ***net.***

Wells and Springs of Derbyshire. By J. V. Stephens, B.Eng., B.Sc. 155 pp. ; 5 text-figures. 1929. Price 4*s.* ***net.***

The Country around Oswestry. (Explanation of one-inch Sheet 137 : England and Wales). By C. B. Wedd, B.A., B. Smith, M.A., Sc.D., W. B. R. King, M.A., and D. A. Wray, M.Sc., Ph.D., with contributions by T. C. Cantrill, B.Sc., and H. H. Thomas, M.A., Sc.D., F.R.S. 234 pp. ; 4 plates ; 14 text-figures. 1929. Price 5*s.* 6*d.* ***net.***

The Geology of the Country around Sudbury (Suffolk). (Explanation of one-inch Sheet 206 : England and Wales). By P. G. H. Boswell, O.B.E., D.Sc., Professor of Geology in the University of Liverpool. 74 pp. ; 2 plates ; 17 text-figures. 1929. Price 2*s.* ***net.***

The Country around Moreton in Marsh. (Explanation of one-inch Sheet 217 : England and Wales). By Linsdall Richardson, F.R.S.E., with contributions by A. E. Trueman, D.Sc., Daisy M. Williams, M.Sc., R. C. Gaut, M.Sc., and H. G. Dines, A.R.S.M. 162 pp. ; 6 plates ; 9 text-figures. 1929. Price 4*s.* 6*d.* ***net.***

The Geology of the Country around Aldershot and Guildford. (Explanation of one-inch Sheet 285 : England and Wales). By H. G. Dines, A.R.S.M., A.M.Inst.C.E., and F. H. Edmunds, M.A. Palaeontology by C. P. Chatwin, M.Sc. 182 pp. ; 5 plates ; 11 text-figures. 1929. Price 4*s.* 6*d.* ***net.***

Scottish Memoirs published in 1929

Summary of Progress.—See above.

English Memoirs in the press at the close of 1929

Wells and Springs of Gloucestershire.

Wells and Springs of Worcestershire.

The Geology of the Alnwick District. (Explanation of one-inch Sheet 6 : England and Wales).

The Geology of the Maryport District. (Explanation of one-inch Sheet 22 : England and Wales).

The Geology of the Country around Huddersfield and Halifax. (Explanation of one-inch Sheet 77 : England and Wales).

Scottish Memoirs in the press at the close of 1929

The Geology of North Ayrshire. (Explanation of one-inch Sheet 22 : Scotland).

The Geology of Ardnamurchan, North-west Mull and Coll. (Explanation of one-inch Sheet 51 and part of Sheet 52 : Scotland).

Geophysical Work

At the close of 1928 Drs. McLintock and Phemister were engaged on the gravitational survey of the Portobello fault which forms the

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north-western boundary of the Midlothian coalfield. This fault passes through level ground about three miles south-west of Edinburgh and the absence of marked surface features was one of the reasons for selecting that area for a test. Where there are elevations and depressions there are great difficulties in interpreting the results obtained by means of the Eötvös balance, as a minute survey of the topography has to be carried out and elaborate calculations are necessary in order to make allowance for the disturbing effect of the irregular surface features. The field work also was carried out during the winter season to avoid interference with agricultural operations and to secure the absence of cattle from the fields. Most of the observations were made between sunset and sunrise as variations of temperature, and possibly other less obvious causes, seem to render it difficult to get perfectly steady readings of the position of the beams of the balance so long as the sun is above the horizon.

The field unit consisted of two geologists, with two assistants and a labourer, who also acted as watchman. The programme of work was not finished by the New Year, but after the holidays it was resumed and completed in January. Thereafter the mathematical calculations had to be performed and the results reduced; during the execution of the field work a preliminary series of calculations had been made in order to give indications of the best line to follow in making the survey and the best positions for additional stations. As a rule only one set of observations was made each day; this involved the reading of the balance in seven positions on a given station; the balance was then shifted to another station and the process repeated. Fifty-three stations were ultimately established in an area measuring about half a mile by half a mile. From this it will be understood that the problem was very fully investigated, and, as a means of testing the evidence given by the Eötvös balance on a structure of this type, the research proved completely satisfactory.

Although the fault could not be seen in any natural exposure within several miles of the site, its position was inferred from general evidence of a sufficiently satisfactory character and was laid down on the published six-inch maps. This inferred position proved to be accurate within about 200 yards; at any rate the evidence of the Eötvös balance survey would lead to a displacement of the line to a distance not greater than this. The rock surface was covered by 'drift' consisting of clay, sand and gravel to an unknown depth, perhaps sixty feet or less, but in a small quarry about 400 yards from the selected site there is an exposure of Carboniferous limestone that indicates clearly the nature of the underlying strata. At a very early stage in the work it was found that the balance proved a marked disturbance of the gravitational field along a line parallel to and not far from the presumed outcrop of the fault. By the end of 1928, as was stated in last year's 'Report,' the position of the fault had been located with sufficient accuracy. A rather striking result of the survey, however, was the proof afforded of a

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considerably greater gravitational gradient than had been anticipated. The most plausible explanation of this was the presence on the west side of the fault line of a mass of rock of exceptionally high density. As the Lower Carboniferous lavas of Arthur's Seat are believed to occur in this ground it was easy to assume that the fault had brought these heavy rocks up to a short distance below the surface. This seems so reasonable and probable that in the new issue of the Edinburgh Sheet (32, Solid edition), which was in the press, the lavas have been shown as lying immediately below the cover of drift at this locality.

In the final discussion of the results of this gravitational survey, which was published in Part II of the *Summary of Progress* for 1928, Drs. McLintock and Phemister have drawn attention to several other inferences of great interest which they have proceeded to deduce from their completed mathematical investigation of the observations. For example, they show that the fault is probably a reversed fault, hading to the upthrow side, and that the rocks adjacent to the fault on the west are probably folded in a small syncline. The axis of the inferred syncline diverges in a marked way from the strike of the fault, being practically north, while the fault runs in a north-north-east direction. They conclude also that the strata on the east side of the fault are very steep and possibly overturned. On the assumption that the lavas have a density of 2.82 the observations indicate that the depth to their upper surface is approximately 150 feet and their total thickness is 500 to 600 feet. These inferences are entirely based on the mathematical interpretation of the results and can neither be confirmed nor disproved by direct observation as there are no outcrops : it would be very interesting to see whether they could be definitely established by a series of borings.

The lavas of the Whinny Hill, Arthur's Seat, are mostly basalts and mugearites, which presumably contain much magnetic oxide of iron. If they are much closer to the surface of the ground on one side than on the other side of the Portobello fault it should be possible to detect their presence by means of a sensitive magnetic balance. As will be seen in a later paragraph, we are now in possession of very delicate magnetometers which seem exactly the right instruments for a test of this order. Accordingly it is intended during the coming field season to make a magnetic survey of the ground investigated with the gravitational balance at Portobello, and it will be very interesting to learn whether the two perfectly independent methods of geophysical investigation yield concordant results.

As stated in my Report for last year (p. 36), an order had been placed in 1928 for a pair of Schmidt magnetic balances, horizontal and vertical, of standard pattern. These instruments were purchased from the Askania Company of Berlin through their London agents and were delivered early in 1929. They represent the most modern type of magnetometers, as adapted for geophysical surveys

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in the field, and similar instruments are extensively in use in many parts of the world.

As soon as they were received Mr. Hallimond took them to Kew and to Abinger where they were examined under known conditions at the magnetic observatories. They passed the tests satisfactorily, and it was decided to use them on a geological problem as soon as the weather was suitable for field parties. The magnetometers are small and compact instruments, easily transported, though they must be handled with care and preserved from shocks if the readings are to be reliable and uniform. In the field also they are very handy as compared with the gravitational balance, as one man can carry each balance from point to point. The Eötvös balance requires from three to five or even seven hours for the complete set of observations on a single station. The magnetic balances are much quicker to operate; in fact the readings necessary at one station may be made in ten to fifteen minutes. Consequently while one or at most two gravitational stations can be done in 24 hours, it is not difficult to do ten or more magnetic stations, and the work is simpler, more rapid and much less costly.

The first problem selected for an experiment in geophysical magnetic surveying was the well-known Swynnerton dyke in Staffordshire. It had already been the subject of a gravitational survey by Dr. McLintock and Dr. Phemister and was especially well suited for a magnetic survey because the country rock in which it occurs is red Triassic marl which cannot be expected to have magnetic properties, while the dyke itself is a basic igneous rock belonging to the nepheline-basanite family, and had been proved by microscopic examination to be rich in iron oxide minerals, most of which are highly magnetic. The dyke is exposed at the surface at intervals over a distance of several miles, and its outcrops are fully shown on the Geological Survey maps. At its south end, however, it disappears from view and is covered over by superficial deposits, or it may indeed not actually have risen to present surface level through the Triassic marls of the country. As the approximate position of the dyke where it is concealed was pretty well-known from its general direction in the exposures to the north, it was expected that no difficulty would be encountered in tracing its buried course for some distance at least.

These anticipations were realized and Mr. Hallimond was successful in locating the unexposed southern end of the dyke for a distance of three miles beyond its known outcrops. The evidence of the magnetometer was completely satisfactory owing to the strong reaction given by the dyke rock as compared with the sedimentary rocks on each side. Moreover very clear indications were obtained that the dyke in its buried southern extension splits up into two or three branches, of much smaller width than the main dyke. Towards the south end of the ground surveyed it was found that the proximity of the railway lines had a tendency to influence the magnetometer strongly and to obscure the effect of the igneous

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rock, but, apart from this, the indication of the presence of the dyke was so clear as to be unmistakable. Moreover by the varied strength of the disturbance on the magnetometer an approximate estimate could be made of the depth of the top of the dyke rock below the surface of the ground.

A short description of this field survey has been published in the *Mining Magazine*.[1]

The success of this investigation was sufficient to encourage the staff to attempt a more ambitious programme. It was already known that in the neighbourhood of Melton Mowbray there is a district in which the magnetic field shows many irregularities, some of them being of a pronounced kind. This ground was the subject of a magnetic survey by G. W. Walker and his results were published by the Royal Society accompanied by a discussion of the local geology and the probable causes of the magnetic irregularities by Professor Cox.[2] As instruments suitable for rapid field work had now been obtained it seemed advisable to make a more complete examination of this ground, and Mr. Hallimond, accompanied by a technical assistant, began this work in September. As the district is easily accessible the field work was not carried out continuously but at intervals, as other duties permitted, over a period lasting for about ten weeks. By the end of the year about 372 stations had been observed in an area extending about nine miles from east to west and about eight miles from north to south. The results are of extraordinary interest as they show a variation of magnetic strength ranging from over 200 magnetic units above, to over 200 units below, the readings given at Woodlands, which is taken as the standard locality as there the constants of the magnetic field had previously been measured by Professor Walker. After allowance is made for the daily variation of magnetism and all other extraneous influences it is clear that in this area the geological structure produces very important magnetic effects. A map prepared by Mr. Hallimond to show the magnetic contours establishes that there are several magnetic 'highs' separated by magnetic 'lows.' The highs are apparently rounded or dome-shaped areas with generally one axis longer than the other so that the contour lines tend to have elliptical forms. The axes of the elliptic contours are directed slightly north of east and this is also the direction of a considerable fault which crosses the area near Sileby.

The rocks of which the country consists are Trias marls, Rhaetic and Lower Lias, covered by boulder-clay, gravel and alluvium, none of which can be expected to have strong magnetic properties. There is good reason, however, to believe that these rocks rest on a floor of Charnian grits and slates, penetrated by granite bosses. In fact, at the west end of the area investigated, the granite rises to the surface at Mount Sorrel, where there are extensive quarries

[1] *Mining Mag.*, vol. xli, 1929, pp. 16-22.
[2] *Phil. Trans. Roy. Soc.*, Series A, vol. ccxix, 1919.

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for road-metal. Now as the magnetic survey is carried forward in this direction it is found that the anomaly rises to its highest values (well over 200), a clear indication that the granite has strong magnetic properties. The probable solution, or one of the possible solutions, of the magnetic variations detected by the magnetometer in the country to the east of Mount Sorrel is that masses of granite lie buried beneath the surface at variable depths. The older Charnian series of slates, etc., into which the granite is intruded are probably less magnetic than the granite. Another possible hypothesis is that masses of dolerite may have penetrated the strata as dykes and sills such as are known to occur in the Leicestershire coalfield. This hypothesis was favoured by Professor Cox in his interpretation of Professor Walker's magnetic survey, but it seems on the whole less likely to be true. Unfortunately there are no borings in this country that might give accurate information as to the depth to the pre-Cambrian floor and conclusions must be drawn mainly from the known composition and properties of the older rocks where they emerge to the surface in Charnwood Forest.

The general results of Mr. Hallimond's survey of the Melton Mowbray ground are at present under discussion and will be published when the investigation has reached a more advanced stage. The difficulty of interpreting magnetic surveys is considerable as not only do rocks differ greatly in their magnetic properties but there are certain kinds of rock such as dolerite of which different specimens vary greatly in magnetic strength. The most magnetic of all minerals is magnetite; other oxides of iron and all silicates have very low magnetism. Hence the local concentration of magnetite, or the local substitution of hematite, limonite or ilmenite for magnetite produces great differences in magnetic strength. Such variations are frequent in igneous rocks even when these are fresh and in their original condition, but in weathered specimens the changes due to oxidation, hydration and decomposition have also to be taken into account. These will generally reduce the amount of magnetite present but may occasionally act in the opposite direction. Thus, for example, where olivine is decomposed to serpentine much fine black magnetite often makes its appearance in the cracks and on the surfaces of the crystals. Another agency that must be taken into account is contact alteration, which sometimes produces magnetite from other forms of iron oxide minerals that are more common in sedimentary rocks.

The specific gravity of rocks undoubtedly varies less than their magnetic properties. It is at the same time fairly uniform in rocks of the same class, and the relations between the specific gravity and the composition, age, history and state of preservation of the commoner types of rock are sufficiently close and sufficiently well understood to render this property of very general use in interpreting geophysical explorations. For this reason it is not uncommon to combine gravitational with magnetic surveys as the one process will supplement the other, and if the indications are concordant they will

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greatly strengthen the conclusions attained. The use of the Eötvös balance in the field is slow, laborious and costly, but it was decided to make a few observations of this nature in the Melton Mowbray district. A line near Thrussington was selected as showing a considerable magnetic gradient in a locality where the conditions were on the whole favourable for a gravitational survey. Accordingly in December Dr. McLintock and Dr. Phemister proceeded to Thrussington and took measurements of the gravitational field at a few stations. Their results showed that the magnetic and gravitational gradients were in the same direction but the magnetic anomaly was much the larger of the two. This is in accordance with expectation but the results were not sufficient to serve as a basis for detailed discussion. The pressure of other duties towards the close of the year prevented the execution of a prolonged programme of gravitational work.

In this short field campaign opportunity was also taken to test the performance of the type of Eötvös balance that is made in Hungary by Süss of Budapest. Through the kind agency of Sir John Cadman one of these balances belonging to the Anglo-Persian Oil Company was placed at our disposal. It was sent to Melton Mowbray along with an English balance and it proved to be very efficient. It differs in construction considerably from the English instrument and is not provided with automatic photographic registration, but the officers who worked with it in the field have been much impressed with its steadiness and accuracy and have recommended the purchase of a balance of this type to be used as occasion requires for further gravitational surveys in Britain.

Soil Mapping

During the year co-operation with soil investigators has been continued. The Development Commission, with the Ministry of Agriculture and Fisheries, again organized a field meeting which was held in September at Chippenham in Wiltshire. The meeting, which occupied one week, was attended by twenty-one members representing British agricultural institutions, a representative of the Imperial Forestry Institute, four Imperial overseas visitors, and by Herr Schlacht of Germany and Mr. Lee of the United States, with Messrs. Dines, Simpson and Allan of the Geological Survey.

A useful innovation was the preliminary visit to the ground for the selection of the area to be mapped; this was done by Mr. A. W. Ling of the Agricultural Advisory Office, Bristol, and Mr. H. G. Dines of the Survey staff.

The site chosen lay to the north-east of Hilmarton village, Wiltshire; it occupied an area about 2¼ miles long by ½ mile wide and included Lower Chalk, forming the escarpment edge of the Marlborough Downs, the Upper Greensand and Gault, the lower part of the Kimmeridge Clay, on the escarpment slopes, the Upper Calcareous Grit and Coral Rag, and the Oxford Clay. The ground

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is free from Drift but the geological boundaries are modified in places by downwash.

The soil surveyors were divided into groups, each of which produced a soil map. The three geologists moved from group to group giving geological information where required and observing methods of mapping.

The results of the survey varied much. Each group produced a map containing detailed information, but no map seemed to be acceptable to the meeting as a whole.

The cause of the variation did not appear to lie in any diversity of opinion as to the description of actual soil samples, but rather in uncertainty as to which of the many soil characters should be taken as the most important factor in the classification. It was generally agreed that the geological map formed the basis of all the maps, and it was emphasised by Mr. Lee that this must be the case in a country with the geological diversity of Great Britain.

Aerial photographs of the area, on the scale of 6 inches to 1 mile, were supplied to the members of the survey party and proved of great value in mapping. Topographical details which are omitted from the Ordnance maps could be readily recognized, thus saving time in fixing positions on the ground. Changes in natural vegetation, implying differences in soils, were apparent. It is considered that the use of such photographs would greatly increase the speed and accuracy of a soil survey.

During the meeting Mr. Lee explained in detail the organization and methods employed by the Soil Survey of New Jersey, U.S.A.; and Herr Schlacht's method of taking soil samples on strips of cardboard coated with adhesive material was demonstrated. Some modification of this method might be useful in the preparation of museum exhibits.

The Chippenham field meeting was followed by a meeting of the Soil Mapping Sub-Committee, held in London in November, which was attended by several members of the Survey staff. This meeting showed that a distinct advance had been made during the year in the direction of unanimity regarding soil classifications and the technique of soil mapping. In both these fundamental subjects much remains to be settled by agreement before real progress can be made.

In June arrangements were made for Dr. Brade-Birks and Mr. Basil Furneaux of the South-Eastern Agricultural College, Wye, to study geological and soil mapping for two days under the guidance of Mr. Dines.

Soil mapping has been commenced by the staff at Dartington Hall, Totnes, Devon. In November Mr. Howe discussed the subject with the Director, Mr. L. K. Elmhirst, and Dr. W. K. Slater and it was arranged that Mr. Lloyd, who is working in the Torquay Sheet, should give such advice and assistance as was required upon geological matters.

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In Scotland field work was continued in one-inch Sheet 14 (Ayr) by the staff of the Chemistry Department of the West of Scotland Agricultural College under Prof. D. N. McArthur. During the period April to June only one officer was at work but in June the Department was fortunate in securing the services of Dr. C. L. Whittles in place of Mr. C. Louden, who left to take up an appointment in England. Dr. Whittles and Mr. Jack continued the mapping on a textural basis of the valuable agricultural lands in the northern part of the Sheet. It was found necessary to sample more frequently and to check the field observations, made under the variable climatic conditions found in Scotland, by making a series of abbreviated mechanical analyses. Co-operation with the Ayrshire Education Authority was secured and the use of the laboratories of Ayr Academy was obtained during July and August. Ten of the senior scholars rendered valuable voluntary help during these months in analysing, under Dr. Whittles' supervision, the various samples collected. Some 600 samples were dealt with during this period and the examination of the remainder of the 1,450 samples collected was continued during the winter months in the College laboratories in Glasgow. Subsoil samples were taken when the profile appeared to differ from that of the usual boulder-clay. Information was collected at each farm regarding (1) acreage; (2) proportion under crop; (3) type of farming; (4) number of milking cows, sheep, etc.; (5) rotation; (6) drainage; (7) manuring and rental. In addition to the mechanical analyses, each sample is being tested for its 'lime requirement' by the method of Hardy and Lewis, using the quinhydrone electrode. The moisture content, loss on ignition and organic matter of each sample are also being ascertained, and records of the colour of the soil before and after oxidation are being prepared.

Field work will be resumed, it is hoped, early in April and the remainder of the Sheet completed during the coming field season. The one-inch map in course of preparation will be based on the scheme adopted by the late Professor R. A. Berry and his colleagues, and will form a companion to the Soil Texture edition of Sheet 22 (Kilmarnock) published in 1929.

Inspection of Bores and Shafts

Both in England and in Scotland an experienced officer is detailed to visit all borings in progress and all important shaft sinkings. By this means it is possible to keep closely in touch with industrial development, to obtain much information that would in all probability be otherwise lost, and at times to give useful assistance to mine owners by identifying the geological horizons that are passed through.

Mr. Howe reports that the number of new bores and shaft sinkings notified in England and Wales during 1929 was 18. Mr. Templeman has visited 53 boreholes, shafts and adits. Twenty of the notified bores and shafts have been completed during the year

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and the records have been obtained; twelve are still in progress and are under observation; three have been temporarily suspended and one has been abandoned. While inspecting the cores, etc., Mr. Templeman has collected 1,417 specimens, and in the office has done a great deal of work on specimens and documents, under difficult conditions.

Several borings in the west of England have yielded valuable information regarding the stratigraphy, and borings made in connexion with an electrical survey for minerals have proved of great interest; for the present the information is confidential.

The Kinlet boring has thrown much light on the sequence of the Coal Measures in the Wyre Forest coalfield and provides valuable evidence of the contemporaneous relations of the basalt of Kinlet to the Coal Measures of the district.

The Cefn Coed sinkings, near Crynant, Neath, were stopped about the end of the year. They have furnished much information concerning the higher part of the Lower Coal Series in the hitherto unproved area; many plants and lamellibranchs have been collected and a strong development of a marine horizon probably about the position of the Mansfield Marine Bed has been exposed. Throughout the sinking the Survey has been in close touch with Mr. W. D. Ware, who has watched the operations and collected material.

The close association between the Survey and the mining engineers and managers during the process of boring and sinking is not only helpful to the Survey but is evidently much appreciated at the mines, and increasing interest and care is taken to provide exact geological information. We are indebted to Mr. A. Alec Jones, of the Hodbarrow Mining Company, for a very carefully executed plan of the strata and faults met with in driving the Moorbank adit.

Mr. Murray Macgregor reports that under Section 23 of the Mining Industry Act (1926) forty notifications of borings or shaft sinkings were received in the Scottish office during 1929. Eleven of these notifications included two or more borings.

Visits to borings and sinkings have been mostly made by Mr. Manson, but frequently the geologists concerned in mapping the ground have also inspected the cores. Copies of the journals have been obtained and checked, while fossils and specimens of rocks taken from bores and sinkings have been placed in the Survey collections. The exact sites of all bores and shafts have been inserted on the six-inch working maps and in nearly all cases records have been prepared in graphic form to allow of ready comparison with the sections of other bores or shafts in the custody of the Geological Survey.

Among the more interesting points which emerge from information obtained at borings or sinkings in Scotland during the year the following may be noted.

In the early part of the year a series of deep borings was put down in order to prove the thickness of the superficial deposits in a part of the broad valley of the River Devon near Devon Colliery,

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Clackmannanshire. A deep pre-Glacial river-course has long been known to exist below the carse-lands of this valley, and in addition to the information obtained by these borings as to the contours of the buried channel, examination of the samples of the deposits brought to the surface shows that there is a well-marked succession of sediments overlying the rock-head.

The following section has been compiled from the three deepest borings :—

		Ft.	In.
Soil		1	0
Yellow clay ...	} Carse Clays...	5	9
Soft dark sandy clay ...		7	0
Sand and gravel (?fluvio-glacial)...		5	0
Clayey sand with layers of clay		21	0
Dark grey ' gutta percha ' laminated clays		64	0
Reddish and brownish ' gutta percha ' laminated clays		120	0
Brown clay with layers of sand		18	0
Clean reddish sand, stones at base	12 to	42	0
Reddish sandy boulder-clay with boulders of porphyrite, felsite, quartzite, Old Red Sandstone and Carboniferous limestone	7 to	51	0
Rock			

Boulder-clay was encountered in all the borings that reached the bottom of the buried channel, and the greatest thickness of this deposit was found in the deepest bore. There was only a small difference in the surface levels of the bores, and the section given above is closely comparable with that described by Mr. H. M. Cadell [1] from the buried channel of the Forth near Bo'ness. The group of deposits lying between the Boulder Clay and the Carse Clays is undoubtedly connected with stages in the retreat of the great ice-sheet, and the thick, laminated, ' gutta percha ' clays were probably accumulated in a late-Glacial sea (sea of the ' 100-Ft ' Raised Beach).

An interesting addition to the fauna of Skipsey's Marine Band has been made by the discovery of *Listracanthus wardi* A. S. Woodward in material tipped from a shaft sinking near Wishaw. In this district Skipsey's Marine Band lies about 53 fathoms above the Ell Coal, one of the highest seams that has been worked in the Productive Coal Measures. It has long been known to yield a molluscan fauna nearly identical with that of the Mansfield Marine Band and its equivalents in England, and although the spines of *Listracanthus wardi* have been frequently recorded from the Mansfield Marine Band they have not previously been found in Skipsey's Marine Band. The present record, therefore, gives additional support to the correlation of these marine horizons in Scotland and England.

The examination of two blind bores in the Lochgelly district of Fife has revealed the presence of fossiliferous blaes overlying the Jewel or Upper Five Foot Coal in the Limestone Coal Group.

[1] Cadell, H. M., 'The Story of the Forth,' 1913, p. 107.

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The shells obtained from this bed have been identified as *Naiadites obesa* (R. Eth., Jun.), and it is interesting to note that this species was figured by Hind[1] from the shale above the Bo'ness Lower Ironstone, which is approximately on the same horizon.

Conferences

The 17th International Geological Congress was held in Pretoria in August by special invitation of the Government of the Union of South Africa. The official British representatives were Professor W. W. Watts (Imperial College of Science and Technology), Dr. L. V. Spencer (British Museum) and Sir John Flett (Geological Survey of Great Britain). The attendance was large and 45 different nations were represented. Many scientific papers were submitted and read and important discussions took place, especially on the geology of Africa. All the British Dominions and Crown Colonies in Africa had sent representatives to the Congress and valuable progress was made in the correlation of strata in different parts of Africa which will greatly facilitate the production of geological maps of the continent. Other subjects discussed were the new International map of Europe and the geological map of the World.

In July the Geologists' Association visited the Brora district of Sutherlandshire and were conducted by Mr. Murray Macgregor, Dr. H. H. Read, Mr. John Pringle and Mr. W. Manson.

Staff Changes

In December Mr. E. B. Bailey, District Geologist, was appointed Professor of Geology in the University of Glasgow and left the service of which he has been a member since 1902. Professor Bailey carries with him the congratulations and best wishes of all his colleagues.

Mr. C. B. Wedd, Senior Geologist, retired on June 13th after 31 years' service and Mr. C. V. Crook, Assistant Librarian, on 30th June after 34 years' service. The vacancy created by Mr. Crook's retirement was filled by the appointment of Mr. E. G. W. Elliott, while Mr. P. A. Frisby succeeded Mr. Elliott and was promoted to Higher Grade Clerk.

Mr. D. Haldane and Mr. G. A. Burnett, Geologists, have been promoted to Senior Geologists, and Mr. A. E. Mourant and Dr. G. H. Mitchell, having been appointed Geologists, have taken up their duties in the Lancashire and Yorkshire areas respectively.

Collaboration

Much assistance has been given by Professor P. G. H. Boswell of Liverpool University in correcting proofs of his memoir on Sudbury

[1] Hind, Wheelton, on '*Carbonicola*, *Anthracomya* and *Naiadites*, Part II.' *Mon. Pal. Soc.*, vol. xlix, 1895, pl. xix, figs. 12-14.

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and by Mr. Linsdall Richardson in the memoirs on the water supply of Worcestershire and Gloucestershire and the memoir on Moreton in Marsh. Dr. R. Campbell of Edinburgh University has corrected proofs of the Stonehaven one-inch map and is writing a memoir on that Sheet. Mr. E. S. Cobbold has specially interested himself in the Cambrian fossils of the Shrewsbury Sheet and is writing an account of the palaeontology of these beds which will include many new observations. Dr. C. E. Tilley of Cambridge has collaborated with the Director in a contribution to the petrology of western Cornwall. As in former years, we have received much assistance in palaeontology from specialists in the various groups; among these we may mention Mr. W. S. Bisat (goniatites), Miss G. L. Elles (graptolites), Dr. Stanley Smith (corals), Dr. A. E. Trueman and Dr. J. W. Jackson (lamellibranchs), Professor H. L. Hawkins (echinoids). Professor D. M. S. Watson of London University has continued his studies of the fossil fishes collected in the Orkneys. Miss E. Bolton has assisted Dr. Crookall in palaeobotanical work. Mr. W. D. Ware has done much service in watching the Cefn Coed sinking and making collections of fossils. Professor D. N. McArthur of Glasgow is continuing the late Professor Berry's work on the texture of Ayrshire soils, with the help of his assistants, Dr. Whittles and Mr. Jack. Miss M. Latham of Glasgow University has made determinations of a large series of Scottish ostracods, and Mr. A. G. Davis continues to give valuable information on Tertiary and Secondary fossils of London and the surrounding districts. In the preliminary work of the magnetic geophysical survey Mr. H. L. P. Jolly of the Ordnance Survey has given most valuable advice.

The Survey has representatives on the Local Committees of the Fuel Research Board which undertake the Physical and Chemical Survey of the National Coal Resources. They are Mr. M. Macgregor (Scotland), Mr. R. G. Carruthers (Northumberland), Mr. C. N. Bromehead (Yorkshire and Nottinghamshire), Mr. J. A. Howe (Staffordshire), Dr. T. Robertson (South Wales), and Dr. W. B. Wright (Lancashire). They enable the Geological Survey to maintain a close connexion with the developments of research programmes in the various districts and to provide such geological information as is called for in the progress of the work.

The schemes now under consideration for the institution of a grid system for distributing high-voltage electricity have involved many questions regarding the stability of foundations, trunk lines, etc., and Mr. J. Allen Howe has undertaken the investigation of the geological factors, with the assistance of the District Geologists. These problems are especially urgent in the coalfields where fortunately our information is fairly complete.

The proposed Channel Tunnel has again awakened public interest and a special Committee of Civil Research has been taking evidence. The Director, with Mr. H. Dewey and Mr. John Pringle, has placed

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before the engineers the geological information in our possession that seems to have a direct bearing on the question.

In connexion with an enquiry on the supplies of British radium a special examination of the South Terras mine in Cornwall was made by Dr. T. Robertson and Mr. H. G. Dines. They have prepared a report and have also published a paper on this mine in the *Mining Magazine*.[1]

During the progress of the tunnel which has been made from Loch Treig to Fort William by the British Aluminium Company several visits were paid by Mr. E. B. Bailey and Mr. David Tait to collect information and specimens of the rocks traversed. Special thanks are due to the Directors of the Company and to their engineers for the facilities afforded to the Survey. Mr. B. Peach, a son of our late District Geologist, has written a full account of this tunnel with special reference to its engineering and geological features, which has been published in the *Transactions of the Institution of Mining Engineers* (Vol. lxxviii, Part 4, pp. 212–225).

Palaeontology

ENGLAND AND WALES.—The number of specimens entered in the registers of the Survey reference-collection during the year amounted to 10,300. In addition to these, 2,026 specimens were acquired by purchase and presentation. The most important of these special collections was a fine set of more than 1,500 well localized Liassic fossils, obtained from Mr. L. Richardson. Another collection of much interest was a carefully recorded set of 250 specimens from the Lower London Tertiary Beds, obtained by Mr. A. G. Davis during the excavations for the Morden extension of the City and South London Railway. Among other donations may be mentioned a set of well preserved Cenomanian brachiopods, presented by the late Mr. E. T. Newton, while some interesting additions to the collection of Carboniferous fossils from the North of England were received through the kindness of Mr. C. Edmonds, Mr. R. G. S. Hudson and Mr. E. W. J. Moore.

The examination and naming of fossils collected in the course of current Survey work has been carried out chiefly by Mr. C. P. Chatwin and Dr. C. J. Stubblefield, and to a less extent by Dr. Kitchin, whose time has been much occupied in editorial and supervision work, and other duties. Certain groups of fossils have, as usual, been submitted to specialists who are not members of the staff. In connexion with current field work Mr. Chatwin has determined series of fossils from the area of Sheet 286 (Reigate) and a large collection from the Magnesian Limestone of Sheet 87 (Barnsley). He visited localities in the neighbourhood of Torquay (Sheet 350), in company with Mr. Lloyd, and collected from various beds of the Devonian system. He examined the fossils from the

[1] *Mining Mag.*, vol. xli, 1929, pp. 147-153.

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area of this Sheet that are preserved in the Torquay Museum, in connexion with the revision of the palaeontology of the district, now in progress.

Dr. Stubblefield has been much occupied in determining Lower Palaeozoic fossils collected from the area now being surveyed in Shropshire and Montgomeryshire. He also examined and revised some older collections from the same area. During the summer he visited various outcrops of the Cambrian and Ordovician rocks there, and paid particular attention to some exposures of Middle and Upper Cambrian beds. Reference to some of his results will be found below, in the Report of the Palaeontological Department.

Additions to the Survey collection of Chalk fossils have been named by Mr. Chatwin. These include a series collected by Mr. Hester from the Mucronata Zone at Thorpe (Norwich), among which are several rare and undescribed species of gastropods, and an assemblage of Reussianum species from Aston Hill (Oxfordshire). Among the specimens selected from a collection of fossils presented by Mr. H. Lance-Gray is a fine slab of Bognor Rock, crowded with examples of *Pectunculus brevirostris* J. de C. Sowerby, which will eventually be placed on exhibition.

Mr. Chatwin collated the collection acquired from Mr. W. J. Lewis Abbot, previous to the registration of the specimens by Miss Odell, and he named a series of Pleistocene shells. He also continued the work of collating the fossils in the collection transferred from the Museum of the Geological Society (preparatory to their registration), for the purpose of relegating to a duplicate set the specimens not required for permanent retention. Attention has also been paid to certain unregistered sets of fossils in the reserve collections, and Mr. Chatwin has named series from the Eocene of Hampshire and the Chalk of Trimingham. He has also been much occupied with editorial work.

Miss M. E. Odell has made good progress in her registration-work. She has continued to give attention to the large collection formerly in the possession of the Geological Society, but has also been able to put into permanent order some of the collections recently acquired.

Mr. S. W. Hester and Mr. W. Dewar carried out a large amount of fossil-collecting in connexion with the current Survey work. Visits were made to the districts in Sheets 286 (Reigate), 161 (Norwich), 230 (Ammanford), 151 (Welshpool), 152 (Shrewsbury), 153 (Wolverhampton), 166 (Church Stretton), 86 (Glossop), 87 (Barnsley), 88 (Doncaster), 99 (Chapel en le Frith), 84 (Wigan), 85 (Manchester), and 23 (Cockermouth).

Mr. S. W. Morgan has carried on work in the preparation and registration of museum specimens. Much of his time has been occupied in the selection and despatch of sets of fossils sent out for special study, and the preparation of the records and particulars accompanying them. These loans amounted to 3,742 specimens.

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In the course of curatorial work a large number of museum specimens which have shown signs of decay, owing to the presence of pyrites, have been treated with suitable preservatives. It has been found that it will be necessary to have plaster casts made of a number of types and figured specimens in which the beginning of this deterioration has become evident.

Very necessary work in cleaning the contents of exhibition-cases in the Museum has been carried out by Mr. D. W. Hepple, who has cleaned and painted the interior and shelves of Cases I to XI and XVI to XVIII on the lower gallery, and has also cleaned all the specimens and renovated the mountings in these cases.

Many enquiries have been answered during the year, and assistance has been given to research workers and advanced students who have made use of specimens in the Museum.

SCOTLAND.—Mr. John Pringle has been in charge of palaeontological work in Edinburgh since the beginning of the year. More than 3,300 specimens were collected and added to those stored for reference. These fossils were obtained from the Silurian, Old Red Sandstone and Carboniferous rocks occupying areas comprised in Sheets 15 (Ayrshire), 23 (Lanark), 117 to 122 (Orkney), 126, 128 (Shetland), and in Sheets 3, 5, and 9 (Northumberland). Nearly a third of the total is represented by specimens from borings and sinkings in the Scottish coalfields and in Northumberland. The collecting of the material was carried out by Messrs. Tait, Manson, Eckford, Strachan, and Fisher.

Apart from the fishes and plants from the Old Red Sandstone which have been submitted to Prof. D. M. S. Watson, F.R.S., and Prof. W. H. Lang, F.R.S., respectively, the examination of the material was made by Mr. Pringle, who has also revised the collections obtained several years ago from localities in Sheets 14, 23, 31, 32, 39, and 40. A small, interesting collection of molluscan shells from between the Main and the Smithy Coal at Bridgness Colliery was also examined. The specimens, which are of stratigraphical importance, have been presented to the Geological Survey by Mr. H. M. Cadell of Grange, Linlithgow, who collected them.

A number of specimens worthy of inclusion in the exhibited Survey Collection in the Royal Scottish Museum have been selected for that purpose.

A few choice specimens of Silurian and Carboniferous fossils have been presented by Mr. D. Baird of Muirkirk. These were collected from localities comprised within Sheet 23, an area recently revised by the Survey.

Palaeobotany

During the year 73 microscope slides of fossil plants were purchased from Mr. W. Hemingway of Derby and 13 specimens of coals, 18 microscope sections and 31 transparencies of coals purchased

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from Mr. J. Lomax of Bolton. The latter are for inclusion in the coal exhibit, being assembled by Mr. C. H. Benson under the supervision of the palaeobotanist. A floor-case is completed and illustrates the various types of coals, their physical properties and chemical composition, their origin and uses, stages of mineralization and the factors operating in the production of different coals. The exhibit will include an internally illuminated case showing thin slices of coals and transparencies prepared from them, arranged to illustrate the nature and origin of the fuels, as revealed by their microscopic structure. A transverse section of the stem of *Lepidodendron vasculare* was presented to the Museum by Mr. J. Brown.

Loans of specimens for research purposes have been made to Professor T. G. Halle of Stockholm, who is making a special investigation of the microsporangia of the Pteridospermeae. The specimens included examples of *Neuropteris carpentieri*, *Whittleseya* and *Holcospermum elongatum*. The Kidston Collection of fossil plants has been made considerable use of by British and foreign palaeobotanists who have visited the Museum.

In 1928 Dr. Crookall prepared a catalogue of upwards of 4,000 negatives of fossil plants in the Kidston Bequest, including photographs of specimens not only preserved in the Kidston Collection but also many from various British and foreign museums as well as from private collections. Early in 1929 Mr. E. G. Radley commenced to make prints from these invaluable negatives and most of his time has been occupied with this work. Good progress has been made, and Mr. Radley has dealt with 2,555 negatives. The mounted photographs, arranged alphabetically as to the species concerned, will eventually form an album for ready reference by palaeobotanists and others. An additional print is being made from each negative.

In the course of the year's work the palaeobotanist has made 96 negatives of fossil plants, etc., 2 photomicrographs, 192 prints, and a number of transfer preparations of surface features.

Petrography

The work of the Petrographical Department has been of the usual varied character during the past year and a great number of enquiries from the public, Government Departments, and public bodies has been dealt with. The Petrographer in addition to routine work has been mainly concerned in completing with Mr. Richey a memoir on the Tertiary igneous rocks of Ardnamurchan, which is now passing through the press. Mr. Bailey has also completed his portion of the memoir dealing with the Archaean rocks of the Island of Coll. In addition, current work has involved the description of rocks from the Cheviot Hills, the Lake District and the English Midlands, districts in the course of being surveyed. In Scotland Mr. A. G. MacGregor with the assistance of Mr. Bailey has dealt with the petrography of the Ayrshire lavas and intrusions, and

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the memoir on Sheet 22 (Kilmarnock) has been in the press. He has made further progress with petrographical work in connexion with Sheet 14 (Ayr).

Dr. Read is engaged on a study of the petrography of Sheets 108 (Altnaharra) and 109 (Achentoul) for a memoir now in preparation.

Miss E. Guppy with the co-operation of the Petrographer has been engaged in preparing a memoir comprising all the chemical analyses of igneous rocks made by the Geological Survey.

During the year much material of petrographical interest has been collected from the Orkney and Shetland Islands, the Central Valley of Scotland and the English Midlands. Dr. Matley has presented 11 sliced rocks in illustration of his work on the Lleyn Peninsula and Dr. Greenly has added a suite of 66 rock-sections to illustrate his work in the same region. The Director presented a series of 84 specimens and sections of igneous rocks from Ayrshire.

The number of sliced rock-specimens and corresponding sections registered in the collections and housed for reference in the Petrographical Department in London is as follows:—

English and Welsh	14,962
Scottish	27,285
Irish	451
Foreign	2,814
Total	45,512

This represents an aggregate increase of 1,130 in the registered sliced specimens during the past year.

Of the corresponding sections 171 have been presented, and the remaining 959 have been prepared in the London and Scottish offices.

Photography

Mr. J. Rhodes has been employed in taking geological photographs and views, mainly in the districts of Surrey, Lancashire, Yorkshire, Shropshire and Glamorgan, to the number of 339. He has also prepared a large number of photomicrographs, miscellaneous photographs and enlargements.

The number of registered negatives is now as follows:—

English photographs ...	4,942
Photomicrographs	1,925
Miscellaneous...	2,052

Prints to the number of 1,370 have been made in the London office, chiefly for incorporation in the Survey albums in the London and Scottish offices.

Mr. Rhodes has mounted 1,107 prints and 758 descriptive forms, for use in the English and Scottish libraries and provincial offices.

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Chemistry

The number of analyses registered in this Department's records at the end of 1929 is as follows :—

English	347
Scottish	520
Irish	2
Welsh	55
Others	50
	974

Of these, fifteen have been completed during the year and four are still in progress. Ten qualitative analyses have been carried out for Survey officers and numerous enquiries from various sources have been dealt with.

Museum of Practical Geology

No important changes in the exhibited collections have been possible during the year, and museum work has been necessarily restricted to cleaning, registration, and partial re-arrangement of selected exhibits. The display of recently published Survey maps has been kept up to date and forms a much consulted exhibit on the Ground Floor. The cases illustrating cement and coal have been re-arranged, and new material incorporated. Cataloguing has been carried out on an extensive scale in the mineral and photographic departments, and a large number of prints of Survey photographs was made for public orders. The preparation of an album of photographs of the Kidston Collection of fossil plants is well advanced.

The Library continues its steady expansion and is increasingly used by students and research workers.

Research work has mainly been occupied with geophysical methods of surveying, accounts of which are given elsewhere.

List of Donations during the Year 1929

Adams, A., Esq.—Lapis Lazuli.

Allegra, Signor.—Garnet-bearing rock from Lanzada, Province of Sondrio, Italy.

Australian & General Asbestos Company Ltd.—Chrysotile from Sherlock, Western Australia.

Barnard, G. C., Esq.—Bismutotantalite from Buganda Province, Uganda.

Bell, E. W. W., Esq.—Portion of lower jaw of *Asteracanthus medius* (Owen), from the Great Oolite series of Yorkshire.

Butler Collection, (*per* Palaeontological Department).—Montmorillonite and angular quartz from Betchworth, Surrey. Barytes from Nutfield, Surrey.

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CLARKE, E., Esq.—Gold-bearing quartz from Rainbow Lake, Patricia District, N.W. Ontario.

COLE, R. S., Esq.—Banded limonite and haematite.

CRAIG, R. B., Esq.—Barytes from Meggen, Westphalia.

DE MEL, H. L., Esq., C.B.E.—A series of samples of graphite, mostly from Colombo, Ceylon.

DIX, Miss E., M.Sc.—Two specimens of *Eumorphoceras bisulcatum* Girty, from the basal beds of Millstone Grit, Llanrhidian, Gower, Glamorganshire.

DIXON, E. E. L., Esq., A.R.C.Sc., B.Sc.—A series of specimens from the Skiddaw Slates of Keswick, Cumberland. 'Drewite' from sea-floor off Great Bahama Bank. Limestone from sea-floor, used as road metal, British Honduras.

DRAKE, W. T., Esq.—Enhydros.

EDMONDS, C., Esq., C.C., J.P.—A series of specimens from the Skiddaw Slates of Blake Fell, Lamplugh, and Ullock Pike, Skiddaw, Cumberland.

FISHER, F. H., Esq.—A specimen of *Anthracomya fisheri* W. B. Wright, from above the Doe Mine, Pendleton Colliery, Lancashire, figured by Dr. W. B. Wright in 'Summary of Progress' for 1928, Part II (*Mem. Geol. Surv.*), Paper iv, p. 47; Plate I, figs. 4, 4A, 4B.

FLETT, SIR JOHN S., K.B.E., F.R.S.—Chrysotile from Shabani and chromite from Selukwe, S. Rhodesia. Eighty-four rock sections from Sheet 22, Scotland.

FRAMPTON, REV. R. E. C.—Volcanic dust from St. Vincent.

GASTER, C. T. A., Esq., F.G.S.—Three specimens of *Saccocoma cretacea* Bather, from the Chalk (*Actinocamax quadratus* Zone, Subzone of *Saccocoma cretacea*) of the Worthing District, illustrative of his paper and that by Dr. Bather in *Proc. Geol. Assoc.*, vol. xxxv, 1924, pp. 89-121.

GREEN, F. G., Esq.—String of 'African Jade' beads and six mineral specimens from South Africa.

GREENLY, DR. E.—Fifty-eight rock sections in further illustration of his work in Anglesey and the adjacent mainland.

HENDRIKS, Miss E. M. LIND.—A series of specimens containing fragments of fossil wood, from various localities in South Cornwall.

HOPTON WOOD STONE FIRMS, LTD.—A series of six polished slabs and three polished cubes of Hopton Wood stone.

HUDSON, R. G. S., Esq., M.Sc, F.G.S.—Five specimens (with microscope-slides) of species of *Orionastraea*, from the Yoredalian (Orionastraea Zone) of Yorkshire.

JACKSON, H. STANLEY, Esq.—Two cut specimens of tourmaline.

KENNY, J. P., Esq.—Nephrite from Teremakan River, New Zealand.

KING, W. B. R., Esq., O.B.E., M.A., F.G.S.—Three specimens and seven microscope-slides of *Streptelasma sp.*, from the Crinoidal Limestone of Graig Wen, Montgomeryshire.

LANCE-GRAY, H., Esq.—A large slab of the Bognor Rock Bed containing numerous examples of *Pectunculus brevirostris* J. de C. Sowerby; also sundry fossils from the Portland and other formations.

MATHEWS, CHARLES, Esq.—Emerald from Lydsdorp area, N.E. Transvaal.

MATLEY, C. A., Esq., D.Sc., F.G.S.—A series of Graptolites from the Caradocian of Pwllheli, Carnarvonshire.

MOORE, E. W. J., Esq., B.Sc., A.I.C.—Several specimens of Carboniferous Cephalopoda from North Devon, Lancashire and Yorkshire, including *Goniatites granosus* (Portlock), *Goniatites newsomi* Smith, *Gastrioceras listeri* (Martin), *Reticuloceras reticulatum* (Phillips), *mut.* β Bisat, and *mut.* γ Bisat.

MORRIS, H. F. WARRINGTON, Esq.—White barytes from Gleniff, Co. Sligo.

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NEWTON, E. T., Esq., F.R.S., F.G.S., F.Z.S.—A series of Brachiopods from the Cenomanian limestone-lenticles in Harris's Pit, Shenley Hill, near Leighton Buzzard, Bedfordshire.

NOTT, F. R., Esq.—Two ornaments carved in tremolite rock and stained to imitate jade.

PENBERTHY, Major F.—Gypsum enclosing sand from the Sahara Desert.

POCOCK, R. W., Esq., M.Sc., F.G.S.—A fine specimen of *Pseudoglyphea etalloni* Oppel, from the Capricornus Zone of New Quarry, Bowlditch Radstock, Somerset; and a fine specimen of *Meristina tumida* (Dalman) from the Wenlock Limestone of Malvern, Worcestershire.

READINGS, T., Esq.—Tooth of marine reptile *Polyptychodon sp.*, from the Bargate Stone of Godalming, Surrey.

ROBERTS, Hugh M., Esq.—Specimens of iron ores from Mesabi Range and Vermilion, Minnesota, U.S.A.

SLAVIK, Professor F.—Specimens of iron ores from Bohemia.

SMYTH, L. B., Esq., M.A., Sc.D., M.R.I.A.—Two specimens of *Palaeacis axinoides* Smyth, from the Lower Carboniferous of Hook Head, Co. Wexford, illustrative of his paper in *Sci. Proc. Roy. Dublin Soc.*, vol. xix, 1929, p. 125.

STEVENSON, A. G., Esq.—Twelve rock specimens from Sheets 105 and 119, Scotland.

STRAKER, E., Esq.—Series of slags from ancient iron-smelting sites.

SYKES, S., Esq.—Large polished section of tin 'pipe' and a series of specimens of cassiterite from Mutue Fides Mine, Transvaal.

TEMPLEMAN, A., Esq.—Seven specimens of *Goniatites striatus* J. Sowerby, from the Highest Limestone (? Cyathaxonia Subzone) in a new quarry at top of hill-slope, south of Pindale Farm, Hope, Derbyshire; and three specimens of *Orionastraea garwoodi* Hudson, from the Carboniferous 4th Limestone of Broughton Craggs Quarries, N.W. of Papcastle Railway Station, Great Broughton, Cumberland.

WHITTARD, W. F., Esq., Ph.D., A.R.C.Sc., D.I.C., F.G.S.—Three hand specimens and fifteen microscope-sections of *Phaulactis* and *Streptelasma* from the Valentian of Shropshire.

WICKLOW OCHRE & MINERALS GRINDING Co., Ltd.—Yellow ochre from the Vale of Avoca, Co. Wicklow.

JOHN S. FLETT,
Director.

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II. DISTRICT REPORTS

(A)—ENGLAND AND WALES

1. SOUTHERN DISTRICT

HENRY DEWEY, District Geologist.
H. G. DINES, A.R.S.M., A.M.INST.C.E.
W. LLOYD, B.SC.
F. H. EDMUNDS, M.A. } Geologists.

IN the Southern District the survey of the Reigate map (Sheet 286) is nearly complete and the writing of the memoir has been commenced by Messrs. Dines and Edmunds. Mr. Lloyd has devoted the season to further necessary field work around Torquay and Totnes and has made progress with the memoir. During the early summer two members of the staff of the South-Eastern Agricultural College, Wye, Kent, accompanied Mr. Dines in the neighbourhood of Bletchingley and Godstone in order to study the methods used in geological surveying and to examine the soils derived from the different divisions of the Lower Greensand formation. Mr. Dines also attended at the Soil Conference and Field Meetings held at Chippenham in September, by the Ministry of Agriculture, where he gave an account of the geological formations of that district and explained the significance of geological maps. In the early spring Mr. Edmunds continued the examination of the Coombe deposits in Hampshire and in Sussex: the results will be embodied in an Appendix in Part II of the *Summary of Progress* for 1929.

Messrs. Dines and Edmunds in accordance with the programme of work, commenced a survey of the Drift deposits around Saffron Walden and mapped the gravels along branches of the rivers Cam and Granta. The Pleistocene deposits present a complicated problem and further work will have to be devoted to the district during the 1930 field season.

Messrs. Robertson and Dines on completion of their survey of the old South Terras Uranium Mine and also of the Tolgarrick Mine, near Grampound Road, Cornwall, published a full account in the *Mining Magazine*.[1]

Mr. Dewey devoted two months in the spring to a re-examination of the killas of the Breage and St. Anthony country and its relationship to the rocks of the Lizard complex: it is expected that this enquiry will be resumed in 1930. He also assisted Mr. Lloyd for a few weeks in South Devon.

Government and Public bodies and the general public make ever-increasing demands upon the time of the staff and the number of

[1] *Mining Magazine*, vol. xli, 1929, pp. 147-153.

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enquiries during the past year approached 500 in the Southern District alone; most of these were about water supply, but others that required much time for consideration relate to sites for tunnels, buildings and wharves.

Three memoirs were published: 'The Country around Moreton in Marsh,' 'The Geology of Aldershot and Guildford' and 'The Geology of Sudbury.' A new edition of the Windsor Map (Sheet 269) has also been issued.

Reigate Sheet

Wealden Beds.—Mr. Dines has found that near Lingfield numerous small exposures afford evidence that the upper boundary of the Tunbridge Wells Sand had been drawn too far south on the old series geological maps, Sheets 6 and 8. Topley [1] was in doubt as to the correct position of the boundary line he adopted and the new evidence is in favour of the extension northward of the Tunbridge Wells Sand by nearly a mile.

Between Outwood and Crowhurst some beds of sandstone in the Weald Clay have been mapped, but they appear to be lenticular masses rather than continuous beds. Some of the sections formerly recorded are completely obscured. Such sandstone beds form the large area of high ground at Outwood where they dip gently northwards. From west of South Godstone to Crowhurst a low ridge of clay is overlain by elongated outliers of sandstone and sand and a similar outlier forms the crest of the parallel ridge at Chathill. The presence of strike faults in the Weald Clay is suggested by the outcrop of sandstone at Poundhill and South Park.

Paludina limestone was formerly worked on an extensive scale, especially in the eastern part of the map, but all outcrops are now obscured and the lines representing their boundaries are mainly conjectural. In the west, however, Mr. Edmunds has traced some hitherto unmapped beds of Small Paludina limestone and others of sandstone, both mentioned by Topley,[2] around Norwoodhill and Stanhill Court about two miles eastward of Newdigate. These beds occur as large lenses in the Weald Clay formation. Outcrops of Large Paludina limestone have been noted south of Leith Hill, at two previously unrecorded localities. The mapping has shown a series of gentle folds with east to west axes that affect the Weald Clay. Two small outliers of Weald Clay have been mapped north of Coldharbour.

Atherfield Clay.—This clay has been traced around the base of the Leith Hill mass where it is to a large extent obscured by slipped masses from the overlying Hythe Beds, southward of Dorking, and around Brockham. Near Collickmoor Farm, Coldharbour and

[1] 'Geology of the Weald' (*Mem. Geol. Surv.*), 1875, p. 98.
[2] *Ibid.*, p. 105.

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south-west of Betchworth, respectively, specimens of the Perna Bed,[1] a shelly bed characteristic of the Atherfield Clay, have been recorded. Inliers have been mapped at Coldharbour, Broadmoor and Friday Street.

Hythe Beds.—Beds of sand and cherty sandstone, the latter often in massive lenticular beds, have been traced around Holmbury Hill, Leith Hill and Coldharbour.

Sandgate Beds.—Mr. Dines reports that the facies of the Sandgate Beds changes from west to east; the grey calcareous sandstone and the fuller's earth beds of the Nutfield area giving place, south of Godstone, to glauconitic sands and sandstones. On the old series geological map the formation is shown as dying out east of Tandridge, but massive beds of glauconitic sandstone at Oxted separate the Folkstone from the Hythe Beds and the outcrop of the Sandgate Beds has accordingly been continued to the eastern margin of the map.

Mr. Edmunds has found that the Hythe Beds of the Leith Hill area have been greatly disturbed, and in places, faulted. A series of small north to south faults, with downthrow generally to the west, occurs east of Holmbury St. Mary, and others around Coldharbour. These faults give rise to extensive landslips in the Leith Hill district, and in this connexion it is interesting to note that the slopes south of Leith Hill are locally termed the 'Slittens.'

The Leith Hill mass appears to have been subjected to shearing stresses from the south due to its position southward of a gap between two strongly developed asymmetrical east to west anticlines arranged *en echelon*; one running north of Dorking, and one through Deerleap Wood. Holmbury Hill, being opposite the middle of the Deerleap fold escaped such stresses, is not faulted, and consequently has no landslips.

An extensive fault, shown on the old geological map as stretching westward from near Dorking to Deerleap Wood and mentioned by Topley[2] is now considered to be non-existent, but one or two tear-faults with approximately a northerly trend are found, as at Deerleap Hill and at Flint Hill, Dorking.

Gault and Upper Greensand.—Mr. Edmunds has mapped these formations from north of Deerleap Wood to Dorking. Near Deerleap Wood the beds dip at a high angle northward and their outcrops are complicated by a small tear-fault.

Chalk.—Along the escarpment of the North Downs the Lower, Middle and Upper Chalk have been shown separately on the map. Mr. Edmunds has ascertained that a gentle syncline with a north and south axis coincides approximately with the valley of the Mole.

[1] Butler, G. W., *Proc. Geol. Assoc.*, vol. xxxiii, 1922, p. 313.
[2] 'Geology of the Weald' (*Mem. Geol. Surv.*), 1875, p. 233.

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Drift deposits.—In the district south of Caterham Mr. Dines has found that outliers of pebble-beds, represented on the old series maps, Sheets 6 and 8, as Blackheath Beds, consist in part of clay with angular flints forming rafts well down in the mass of pebbles. At some localities these outliers rest upon the Middle Chalk, and if they are Tertiary Beds *in situ* they must have been deposited upon an anticline from which the whole of the Upper Chalk had been removed. There is, however, no evidence of such an anticline, and this fact as well as the composite nature of the deposits indicates that the Blackheath Beds may not be in place. Mr. Edmunds has mapped two spreads of Plateau Gravel on the Weald Clay, at Henfold, and half a mile south of Beare Green: both lie at about 310 feet above O.D. The constituent materials have been derived entirely from the Lower Greensand and the Weald Clay.

The 'chevick' or 'shrave' gravel described by Mr. Dines [1] has also been traced by Mr. Edmunds in valleys of small tributaries of the Mole flowing north-eastward between Dorking and Norwoodhill. Two minor instances of river-capture have been observed between Holmwood and Henfold.

H. DEWEY.

[1] 'Summary of Progress' for 1928, Part I (*Mem. Geol. Surv.*), 1929, p. 55.

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2. MIDLANDS AND SOUTH WALES DISTRICTS

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THE field work done in the Midlands during the year lay in one-inch Sheet 167 (Dudley), of which less than half now remains to be surveyed on the six-inch scale. Mr. Pocock's area was centred on Bridgnorth, and included small portions of the Church Stretton Sheet (166) adjoining on the west. Mr. Whitehead's ground lay around Trysull, Claverley and Enville.

In South Wales Dr. Robertson's revision of the Merthyr Tydfil district (Sheet 231) is approaching completion.

Until his retirement in June Mr. Wedd was engaged on the Shrewsbury Sheet (152) and a portion of coalfield falling into the adjacent Sheet 151 (Welshpool). His maps and the description of his ground for the Shrewsbury Sheet memoir have been finished, and the other surveyors have also been occupied with this memoir during the winter. Numerous enquiries by official bodies and the public have been attended to, relating to water supply, foundations for electric power-line 'pylons,' reserves of cannel coal, and other subjects. Mr. Dinham has also been occupied with editorial work, including the memoirs on Oswestry and on the water supply of Worcestershire.

MIDLANDS DISTRICT

Silurian.—A considerable area of Downtonian Beds has been mapped by Mr. Pocock to the west of Bridgnorth; and the outcrop of the Psammosteus Limestone has been traced in the steep scarp of Meadowley Hill, west and south of Morville, over a distance of about two miles.

Old Red Sandstone.—Fish beds, probably belonging to the Lower Old Red Sandstone (Dittonian), have been detected by Mr. Pocock in the sandstones and marls above the Psammosteus Limestone of Meadowley Hill, and at localities in the area to the south-west round Criddon and Chetton.

Coal Measures.—In the small area of these rocks around Tasley, belonging to the Sulphur Coal Group (lower portion of the Upper Coal Measures), the outcrop of the Spirorbis Limestone has been found to agree in general with that shown on the old map.

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The underlying Main Sulphur Coal has not been worked in this area for many years.

The presence of the Spirorbis Limestone in the northern part of the Deuxhill outlier has also been confirmed by Mr. Pocock.

Exposures of the Keele Beds are to be seen at many points both north and south of Bridgnorth, and a Spirorbis limestone has been detected in the Cantern Brook just north of the town.

An important boring for coal at Kinlet, 7 miles south of Bridgnorth, has been examined in detail. It passed through the lower part of the Sulphur Coal Group into the underlying Sweet Coal Group (Middle Coal Measures).

A small area of Keele Beds and a larger one of Enville Beds have been mapped by Mr. Whitehead near Bobbington and Enville. The area is part of the 'South-east Shropshire Region' of Mr. W. W. King's paper of 1899.[1] The calcareous sandstones of the Calcareous Conglomerate Group are found to be numerous but, here as elsewhere,[2] individually very impersistent, so that the number of such beds that may be counted crossing a line parallel to the dip differs considerably from place to place. The calcareous conglomerates occur as sporadic lenticles, of very limited lateral extent, in the sandstones. The overlying Clent (Enville) Breccias are in two main bands (separated by beds consisting chiefly of marl), of which the higher can be traced from Enville nearly to Bobbington and the lower from Enville Sheepwalks to the neighbourhood of Gatacre. Drift and lack of exposures prevent the lower band from being traced any farther at the surface; but that the breccias do persist somewhat farther north is shown by their having been found in the borehole put down in search of coal 520 yds. east of Bulwardine, near Claverley.[3] The impersistence of the calcareous beds in the Calcareous Conglomerate Group renders it difficult to ascertain the exact relation to it of the overlying Breccia Group, and the mapping has not yet proceeded far enough to permit a definite decision as to the conformability or otherwise of the latter in the Enville district.

Trias.—The Lower Mottled Sandstone division of the Bunter, displaying its remarkable false-bedding, is well exposed on Mr. Pocock's ground in the sides of the Severn valley. The Pebble Beds, with basal conglomerate, cap the steep eastern side of the valley, and little change has been found to be necessary in the general mapping of this division. Mr. Whitehead calls attention to the considerable number of Carboniferous Limestone pebbles occurring in the lower portion along the eight-mile escarpment from Abbot' Castle Hill to Kinver. In addition to these, pebbles of volcani

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1 'The Permian Conglomerates of the Lower Severn Basin,' *Quart. Journ. Geol. Soc.*, vol. lv, 1899, p. 97.

2 See T. H. Whitehead in 'The Geology of the Southern Part of the South Staffordshire Coalfield' (*Mem. Geol. Surv.*), 1927, pp. 133 and 144.

3 Gibson, W., 'A Boring for Coal at Claverley, near Bridgnorth,' *Trans. Inst. Min. Eng.* vol. xlv, 1913, p. 30.

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rocks, reminiscent of the Uriconian, and of purple sandstones not unlike those of the Longmyndian, have been noted. These may have been derived from the Clent (Enville) Breccias; but the large average size of the Carboniferous pebbles seems to preclude their having reached the Bunter at second hand, by way of the Enville Beds. The same considerations may be applicable at a much higher horizon, the basal conglomerate of the Keuper Sandstone, which Mr. Pocock finds to contain a high percentage of pebbles of Carboniferous Limestone, up to 6 in. in length.

Superficial Deposits.—The drift problems of the Bridgnorth area are so interconnected with the Severn valley terraces that a discussion must be deferred until the ground to the south has been surveyed in detail.

Boulder-clay is confined mainly to the northern part of the area surveyed by Mr. Whitehead; but in the west extends at least as far south as Gatacre Park. Glacial gravels, forming ridges or mounds, also occur mainly in the north. It is noticeable that these glacial gravels, and the boulder-clay, rarely descend much below 300 ft. above O.D. The concentration of large Scottish and Lake District erratics on the dip-slope of Abbot's Castle Hill is impressive, as is also the suddenness with which these erratics cease, on the east side of the Pebble Bed escarpment, at the north end of Blackhill Plantation.[1] Large erratics of northern origin are, in fact, almost confined to the area north-west of a line from Wombourne to Tuckhill.

Gravels, apparently comparable with those of the Lower Worfe valley,[2] occur extensively around Claverley, where they tend to form flat areas deeply dissected by the present streams.

Along the Smestow Brook and the River Stour near Prestwood and Kinver two terraces have been traced. The higher of these was found nowhere, within the area surveyed, to descend appreciably below 200 ft. above O.D. The gravels of this terrace contain many pebbles of northern origin, including, near Smestow, boulders of considerable size. These gravels can be correlated with those which, at Stourbridge, have yielded mammalian remains.[3]

South Wales District

Carboniferous.—In the Carboniferous Limestone of Sheet 231 it is found that the intra-Avonian unconformity develops a short distance east of Penwyllt, the position of the shore-line intersecting the outcrop near Pwll Byfre. West of this point there is unconformity between the Cleistopora and Upper Seminula Zones,

[1] The 'War Stone' by the roadside at the north-west corner of Blackhill Plantation is a boulder of granite of Criffel type.

[2] Robertson, T., in 'The Country between Wolverhampton and Oakengates' (*Mem. Geol. Surv.*), 1928, p. 193.

[3] Boulton, W. S., 'Mammalian Remains in the Glacial Gravels at Stourbridge,' *Proc. Birm. Nat. Hist. and Phil. Soc.*, vol. xiv, 1916–17, p. 107.

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whilst eastwards the intervening beds appear and thicken gradually to about 60 ft. at Pontsticill, though maintaining their in-shore character.

In the Millstone Grit it is possible by means of the goniatite sequence to make direct comparison with the succession in the north of England, showing that the Reticuloceras and Gastrioceras Zones are definitely present in this district.

The lowest portion of the Coal Measures, namely that below the Garw or Gnapiog Coal, thickens decidedly westwards, and in it appear a number of marine horizons ; it thus shows resemblance to the corresponding portion of the sequence in the Midlands and elsewhere. It has also been found possible to correlate with a high degree of confidence the several coals in the main productive portion of the sequence, the obvious correlations on lithological grounds being checked in many cases by the lamellibranch assemblages.

As regards the western portion of the Sheet, where most difficulty was experienced, the recent sinkings at Cefn Coed near Crynant (Sheet 230) have given invaluable information regarding the higher portion of the Lower Coal Series. The strong development in these sinkings of a marine band probably about the position of the Mansfield Marine Band of Yorkshire, together with the Cwmgorse marine horizons at a higher level, has facilitated more detailed correlation of the higher Yorkian beds of the Vale of Neath. The lower marine band of Cefn Coed has been traced as far east as Rhigos.

C. H. DINHAM.

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3. YORKSHIRE DISTRICT

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THE Yorkshire unit was again deprived, for a considerable period, of the services of two of the staff, Mr. Stephens and Mr. Edwards being employed in Orkney for three months and for a proportional amount of their time in the office. They have completed the mapping of certain small areas in the Glossop Sheet (86) which had been left over pending the identification of fossils. Mr. Bromehead and Dr. Wray have been mainly occupied in office work connected with the publication of the Huddersfield memoir and with the Concealed Coalfield; Dr. Wray has also done a large amount of work on the application to the Yorkshire coalfield of the new methods of zoning by *Carbonicola* and other freshwater mollusca; in this he has been assisted by Dr. Trueman, who has kindly identified specimens and described several new species.[1]

Such time as was available for routine field work Dr. Wray has spent in carrying his work on the north-eastern margin of the Glossop Sheet eastwards into the Barnsley Sheet. It is evident that considerable modifications of the structural geology shown on the original Survey maps are necessary, and some advance has been made towards the exact correlation of several of the important sandstones in the Middle Coal Measures. For this purpose full use is being made of the fossil evidence, both marine and freshwater. A number of important points is arising, but the work is not yet ready for publication as a whole.

The Coal Measure succession ranges from the Flockton and Parkgate coals up to the Oaks Rock. Several important coal seams crop out at the surface; they include in ascending order the Parkgate, Flockton Thin and Flockton Thick, Top and Low Haigh Moor, Barnsley or Warren House, Mapplewell, Beamshaw, Winter and Woodmoor. Practically all the seams have been worked at one time or another along the outcrop. During successive disputes in the coal industry within recent years extensive outcrop workings have facilitated the tracing of the several outcrops and

[1] *Annals and Mag. of Nat. Hist.*, Ser. 10, vol. iv, 1929, pp. 82–95.

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enabled considerable modifications to be made on the original survey. Between High Hoyland and Kexbrough there are many overgrown pit-mounds marking the outcrop of the Tankersley Ironstone, but these do not appear to have been worked since mediaeval times.

To the north of this area and between West Bretton village and High Hoyland some revision of the original survey seems to be called for. The old and disused workings in the Tankersley Ironstone end somewhat abruptly in Deep Haigh and High Woods to the north-east of High Hoyland, and to the north there occur much higher measures which contain the local representatives of the Top and Low Haigh Moor seams. There is evidence, therefore, of an east-and-west fault of considerable magnitude between High Hoyland and West Bretton. Its position can be determined within fairly narrow limits by means of crop workings in the New Hards, Parkgate and Flockton coals to the east of Clayton West.

What are taken to be local representatives of the Top and Low Haigh Moor coals can be traced across Bretton Park past Haigh village to Birthwaite Hall. They appear to be repeated near Haigh by a powerful N.N.W.—S.S.E. fault which has been proved in the New Hards workings at Darton Main Colliery. Thick beds of sandstone are associated with the Haigh Moor coals in the West Bretton and Haigh districts, and one of these beds is being quarried in Haigh village.

The Barnsley Coal shows considerable variations in the present area. These have been already discussed elsewhere.[1] At the present time the bed is being worked in Bullcliff Wood, West Bretton. Between Woolley and Darton it has been largely worked out. At Woolley Colliery it contains the characteristic band of 'hards,' but in the underground workings this band dies out abruptly along a N.E.—S.W. line running from Far Moorhouse, Haigh, past Woolley Hall. The corresponding seam at Crigglestone Main Colliery has been worked under Woolley Edge; it contains numerous thin dirt partings and is devoid of 'hards,' being here described as the Warren House seam.

The Mapplewell, Beamshaw, Winter, Two-Foot and Woodmoor coals which crop out along the slopes of Woolley Edge have all been worked in this district with the exception of the Two-Foot which does not appear to be worth working north of Barnsley. The Beamshaw is being extensively mined at the present time and splits into an upper and lower bed in the underground workings under Woolley Edge.

Above the Woodmoor Coal comes a thick massive gritty sandstone, the Woolley Edge Rock, which between Wakefield and Barnsley produces one of the most conspicuous escarpments in the Middle Coal Measures. At Woolley Edge it is very coarse in grain and was formerly largely quarried, but all the quarries are standing at the present time.

[1] 'The Barnsley Coal and its variations,' Appendix VI in 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, pp. 127–137.

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The Woolley Edge Rock is separated from the succeeding Oaks Rock by about 150 ft. of shale which contains no workable seams of coal. The Oaks Rock is a yellow fine-grained sandstone, very readily distinguished from the underlying Woolley Edge Rock by its relatively fine grain. It is, however, of a variable nature and often contains considerable masses or lenticles of sandy shale.

To the east of Woolley and in the grounds of Woolley Hall occur scattered patches of gravel forming low mounds. These gravels are well stratified and strongly current-bedded. The great majority of the pebbles are small and well-rounded, but occasional large angular blocks of ganister or sandstone also occur; the great bulk of the material is of local origin, though some may have been derived from the Millstone Grits. The gravels bear no relationship to the present drainage, and their origin, though uncertain, is probably fluvio-glacial. The most extensive of these patches at the southern end of Seckar Wood, Woolley, is being worked for fine gravel.

Dr. Mitchell joined the Yorkshire unit early in the spring and has surveyed a considerable area in the north-eastern part of the Barnsley Sheet.

On the west Coal Measures have been mapped, but the greater part of the area surveyed is occupied by rocks of Permian age. It consists of an elevated tract presenting a bold escarpment to the west and gently falling to the east to pass beneath the alluvium of the Don and its tributaries. The Upper Magnesian Limestone gives rise to a subsidiary escarpment to the east of the main scarp formed by the Lower Limestone.

The Coal Measures have been surveyed over an area extending from South Elmsall to Mexborough. They consist in the main of the middle division of that series, though beds referred to the Upper Coal Measures were formerly exposed in the cutting of the Dearne Valley Railway near Cadeby.[1] Over much of the ground mapped the succession is not easy to determine owing to the paucity of exposures. In the cuttings of the Dearne Valley Railway west of Barnborough, however, a thick sandstone occurs which may prove to be the Ackworth Rock. Another prominent sandstone occupies the ground running north from Mexborough towards Adwick on Dearne, in which direction it appears to be cut off by a fault. It is well exposed in several quarries in Mexborough. The Shafton Coal lies a few feet above the top of this sandstone and was formerly worked around Mexborough but the workings are now abandoned and no outcrops are seen. The Measures above the Shafton Coal contain thin coals which are or formerly were exposed in temporary excavations. The study of the concealed Coal Measures as determined by colliery workings gives promise of interesting results.

[1] Culpin, H., and G. Grace, *Proc. Yorks. Geol. Soc.*, vol. xv, 1904, p. 330.

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The Permian rocks of the district are capable of subdivision as follows :—

(f)	Upper Marls	Variegated marls
(e)	Upper Limestones ...	Thin bedded limestones
(d)	Middle Marls ...	Red and grey marls with gypsum
(c)	Middle Limestones ...	Cellular and sugary limestones; wedge-bedded
(b)	Lower Limestones ...	Fossiliferous thick-bedded limestones
(a)	Basal Sands ...	False-bedded white and yellow sands

The lowest member of the succession is impersistent but has been observed at several points. The best exposures occur at Watchley Crag to the south-west of Hooton Pagnell, near Bilham House and in Melton Park.

The lowest limestones are exposed in a series of quarries ranging from South Elmsall to Cadeby, along the line of the escarpment. The railway cutting of the L.N.E.R. Doncaster—Wakefield line at Hampole also displays a good section of these beds. Here the rocks are remarkable for the development of concretions up to an inch or more across, while the oolitic character of the beds is striking. Excellent fossils are obtainable in several places, among which the quarries around Hampole must be mentioned.

The Middle Limestones are well exposed in a section along the South Yorkshire Joint Railway between Hampole and Pickburn. They are remarkable for the frequent wedge-bedding, while other characteristics are their more sand-like appearance when weathered, the cellular nature and the paucity of fossils. The quarry at Hampole Limeworks and the old quarries at Lound Hill, Brodsworth, Pickburn and Sprotbrough afford other exposures of these rocks, but it is not possible to lay down a definite line of junction between Lower and Middle Limestones on the map.

The Middle Marls occupy a belt of lower country along the strike of the rocks, which is in general N.N.W., and extend up the slopes to the scarp of the Upper Limestones. The only exposures of note occur at Brodsworth Colliery Brick Pit and at Sprotbrough Station. At the former locality some 25 feet of red and occasional grey marls are visible with numerous bands of gypsum. The marls may also be seen in the cutting of the South Yorkshire Joint Railway near Skelbrooke Rein where they are faulted against the Upper Limestones.[1]

The Upper Limestones are characterized by their thin bedding. Fossils are not common but have been observed in the upper beds in several localities and in particular at Newton Quarry, about one mile west of Doncaster Station.

The Upper Marls are never well seen but the mapping suggests that several areas previously regarded as Middle Marls must be referred to the Upper Marls. Such outcrops occur in Skelbrooke Park, Burghwallis Park, near Adwick le Street and in the grounds of Cusworth Park, in all cases occupying low-lying and ill-drained ground.

[1] Kendall, Prof. P. F., and H. E. Wroot, 'Geology of Yorkshire.' 1924, p. 918.

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Fluvio-glacial sands and gravel are found in several places, among which may be mentioned Burghwallis, Cusworth and Cadeby. Most of the material comprising them is derived from the Magnesian Limestones, though some Carboniferous pebbles occur.

The structure of the area is comparatively simple, as the Coal Measures are overlain unconformably by the Permian rocks which dip gently with minor folds. The Coal Measures themselves dip gently in a north-eastward direction where exposed. The country is, however, cut up considerably by a series of large faults which trend N.E. The most spectacular is one which, running from south of Bentley Colliery, ranges through Cusworth Park south-westward to beyond Cadeby. In Cusworth Park the Upper Limestones are faulted against the Middle Limestones of the Permian, while the same fault is well seen in the cutting of the South Yorkshire Joint Railway about half a mile north of Sprotbrough.[1] Three similar faults extend across the country to the north, where their effect on the scarp of the Permian rocks is noticeable: one may be seen in the cutting of the South Yorkshire Joint Railway near Skelbrooke, where Upper Marls are thrown against Lower Limestones; another throwing the Lower Limestones against Coal Measure sandstone may be traced in the cutting of the old Hull and Barnsley Railway near Waterfield.

C. N. BROMEHEAD.

[1] Culpin, H., *Proc. Yorks. Geol. Soc.*, vol. xv, 1905, p. 453.

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4. LANCASHIRE DISTRICT

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A. E. MOURANT, B.A.

THE publication of the six-inch maps of the Manchester area is now almost complete and the one-inch map (85) is ready for issue in two editions, Drift and Solid. During the field season considerable progress was made with the Wigan Sheet (84) and a number of six-inch sheets are ready for standardization. A considerable amount of palaeontological work has been done with a view to obtaining an effective correlation across the field and has been attended with some success.

Dr. Sherlock working in the St. Helens district finds that the Trias oversteps the Coal Measures towards the north, for at Eccleston, Bunter rests on variegated strata which appear to be Upper Coal Measures, while at Rainford village it rests on strata well down in the Middle Coal Measures. A number of mussel-bands and a *Lingula*-band have been found in the St. Helens Coal Measures and should prove useful in correlating the coal seams. In Rainford and Windle the new map will show considerable changes, owing to the great amount of information that has accumulated since the existing map was published. Amongst other changes, the large area shown as Middle Coal Measures has been found to be in part Lower Coal Measures.

Mr. Tonks has been working in the north-western part of Sheet 84 where it appears that considerable modifications of the former interpretation of the ground are necessary. On the upthrow side of the Upholland Fault, which forms the eastern boundary of the Middle Coal Measures of the Skelmersdale coalfield, the Millstone Grit is seen in stream sections and quarries west and south-west of Elmer's Green. The main rock is a hard coarse sandstone with beds of coarser grit, and is overlain by shales and sandstones with three thin coal seams. The uppermost coal is followed by a marine band containing *Gastrioceras cancellatum* and *Reticuloceras reticulatum* mut. γ. This is therefore the Holcombe Brook Marine Band, and the main bed of grit is probably on or about the horizon of the Brooksbottoms Sandstone of south-west Rossendale. The higher members of the Millstone Grit Series are here cut out by faulting, and do not appear south of the River Douglas. North of the Douglas, what appear to be the Rough Rock and Haslingden

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Flags are seen in small exposures in the faulted ground west of Harrock Hill, for although the field relationships are by no means clear as yet, the Six Inch Mine Marine Band has been located in three stream sections hereabouts.

The coarse massive grit and sandstone capping the hills sweeping south-west and south from Harrock Hill towards Parbold overlies this marine band and is therefore not of Millstone Grit age as previously believed. It is an enlarged representative of the Ousel Nest or Horwich Grit, extending upwards to within some 20–30 ft. of the Lower Mountain Mine.

The post-Glacial deposits of the West Lancashire district, which has been entered this year, are of special interest in that they include a widespread sheet of wind-blown sands, derived from the coastal area, and called by De Rance the Shirdley Hill Sand. This deposit occupies a large area west of the River Tawd and extends eastwards for a little distance on to the higher ground south of Upholland. It has been removed over considerable areas as it furnishes a valuable glass sand. It appears to be divisible everywhere into an upper 'white' sand and a lower 'brown' sand which are dug and kept separately and used in different processes. The upper 'white' sand is more properly described as pale yellow and is frequently separated from the lower 'brown' sand, which is olive grey and brown, by peaty layers. The extensive peat mosses of West Lancashire overlie the Shirdley Hill Sand, but that peat formation also preceded it is shown by sections in and around the sand pit west of Stanley Firs, ¾ mile north-west of Skelmersdale Station. Here the generalized section is :—

		Ft.	In.
	Peat of Stanley Firs 10 ft. to	12	—
Shirdley Hill Sand	Yellow sand with peaty soil layers 2½ ft. to ...	3	—
	Hard dark peaty sand 1 in. to	—	4
	Yellow and olive grey sand 6 in. to	—	12
	Hard dark peaty sand 1 in. to	—	3
	Olive grey and olive yellow sand with occasional thin streaks of peaty sand 4 ft. to ...	6	—
	Hard black peat 9 in. to	—	12
	Boulder-clay		

This lower peat has also been seen in a sand pit 200 yds. north-east of Upholland Station at a height of 340 ft. above O.D. where 1 ft. of 'white' sand rests on 2 ft. of 'brown' sand, which is separated from the underlying Boulder Clay by some 9 in. of peat.

Mapping has been continued by Mr. Jones for a short period, south of Ashton in Makerfield, where red boulder-clay is found to cover most of the ground. Bunter Sandstone is exposed about this town as well as at Newton in Makerfield and along Sankey Brook. In some cases it is observed to weather yellow, a good example being visible in the railway cutting south of Ashton. Wherever the Bunter Sandstone is seen it contains numerous pebbles. Over 60 per cent. of these are quartzites and fine-grained quartzitic sandstones and show a great variety of colours, reddish, grey, white and

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occasionally black. Vein quartz comprises about 30 per cent. while the remainder were found to include decalcified limestones, one containing crinoid stems, a fine-grained igneous rock, chert, a nodule of haematite, Carboniferous sandstones with 'clay-galls,' and brown silicious fine-grained sandstones probably of Lower Palaeozoic origin.

Mr. A. E. Mourant, after being trained by Mr. Tonks in the northern part of Sheet 84, commenced work in the south-western part of Sheet 75. Here solid exposures are found only in two small areas and little can be done in the way of mapping the Trias beneath the drift.

The position indicated by De Rance for the Scarisbrick Fault separating the Keuper Marl and Bunter Sandstone has been confirmed more precisely by a newly found exposure of marl 500 yds. to the north, and a boring in sandstone 100 yds. to the south of the presumed position of the fault. The nearest solid, known to De Rance, was about a mile away on either side.

The ground consists principally of alluvium, Shirdley Hill Sand and peat on a thick substratum of boulder-clay which occasionally rises to the surface to form low hills.

Large areas of peat have disappeared since the last survey was made. Some of the material has obviously been cut, but much of the loss appears to be wastage due to cultivation. All the peat exposed in the area is obviously later than the Shirdley Hill Sand. A thin peat found beneath the latter in shallow auger holes south of Mere Sands Wood is probably the same as the lower peat found near Upholland and Skelmersdale. Above the main peat other thin beds of sand only differ slightly in appearance from the Shirdley Hill Sand and may be in part aeolian although more probably alluvial in origin. Along a large tract on the northern shore of the drained Martinmere these upper sands are of this latter character, having a pebbly base in places. Where the intervening peat dies out it is almost impossible to separate the two sands, but one section at a point above the general level of the peat, shows Shirdley Hill Sand, with an old soil layer at the top, succeeded by a coarser sand with small pebbles at the base.

In September Mr. Mourant moved on to the Carboniferous near Chorley. Here solid exposures are few. Thick boulder-clay covers most of the ground, while considerable areas of Glacial sand are exposed, especially in the valleys.

Large areas formerly thought to be Coal Measures now appear to be Millstone Grit. For example, in Howe Brook, ¾ m. W.10°S. of the Inn at Heskin Green, and near the base of the Ganister Measures as shown by Hull, the Holcombe Brook Marine Band has been found. The top of the Millstone Grit is now known to be half a mile farther south, at the Brook House Coal of the old map, where Mr. Tonks has found the Six Inch Mine Marine Band in the roof shales of this coal seam.

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The Yarrow valley below Euxton is also almost certainly in Millstone Grit. No fossils are seen, so that palaeontological evidence is not available, but the section, the interpretation of which is aided by several good local borehole journals, agrees with the succession from the Six Inch Mine to the Holcombe Brook Series. A coal, identified as the Sand Rock Mine, has been worked at Bolton Green. The section of the seam is reported to be 2 ft. 7 in. of coal on 1 ft. 8 in. of cannel. It is probable, from the Yarrow section and a few other exposures, that most of the ground north-west of Chorley, up to the Trias boundary, is Millstone Grit.

Lower Coal Measure exposures are almost entirely confined to the beds from the Upper Mountain Mine to the Crutchman Sandstone. The identity of the so-called ' Mountain Mine ' west of Chorley with the Upper Mountain Mine of the Rossendale area has been confirmed by the finding of Tonge's Marine Band in the expected position. The Crutchman Sandstone attains an exceptional development being as much as 88 ft. in thickness and coarser than the local Rough Rock which is here only a moderately coarse sandstone.

Middle Coal Measures are only exposed in the bed of the Yarrow south of Chorley where, at the base of a 15-ft. cliff, the Yard Mine is seen to have a *Carbonicola* roof.

Mining information shows the existence of a block of about ¾ sq. m. of Middle Coal Measures lying under thick drift in the Yarrow valley S.W. of Chorley. This area, formerly mapped as Lower Coal Measures, is faulted down some 1,000 ft. against the latter.

W. B. WRIGHT.

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5. CUMBRIAN DISTRICT

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DURING a comparatively short field season further advance has been made in the re-survey of the Cockermouth Sheet (23) by Messrs. Eastwood, Trotter and Hollingworth.

The former has been engaged chiefly upon the Coal Measures north-east of Aspatria, while Dr. Trotter has been engaged on the Carboniferous Limestone Series near Uldale and Caldbeck. A comparison has been made between the limestone sequence in the latter area and that farther west near Ward Hall and Wood Hall, previously surveyed by Mr. Eastwood. This furnishes a link between the extremes presented by the lithological sequences in East and West Cumberland respectively. Mr. Hollingworth continued his work amongst the Lower Palaeozoic slates, lavas and intrusions of the Caldbeck Fells and on the eastern outcrop of the Carboniferous Limestone.

The preparation of memoirs on Sheets 18 (Brampton), 22 (Maryport) and 28 (Whitehaven) has been steadily carried on.

Skiddaw Slate.—Skiddaw Slates and Watch Hill Grits have been mapped in the area to the south of Great Sca Fell. The former are for the greater part blue-grey banded argillaceous slates which are intensely crushed and contorted, and traversed by numerous minor thrusts of low angle. The relations of the masses of Watch Hill Grits, which cap the high ground, to the underlying beds are clearly abnormal, and evidence that considerable thrusting has taken place in this area is steadily accumulating.

Borrowdale Volcanic Series.—In the Borrowdale Volcanic Series farther to the east a number of distinctive lava types have been recognised and a sequence has been determined in the Caldew valley. Here the porphyritic 'Eycott type' lavas form the most southerly outcrop. These appear in the Caldew near Linewath and are traceable at intervals along the northern outcrop of the Borrowdales. They are succeeded northward for nearly a mile by a great thickness of porphyritic, vesicular, and black compact flow-banded types. The whole succession appears to be overturned to

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the north. One or two thin bands of tuff only are interbedded with these flows, but a large number of bluish-grey basic dykes have been intruded into them. The trend of this dyke swarm is parallel to the strike of the Borrowdales and to the long axis of the Carrock Fell intrusion.

Coniston Limestone Series.—The Drygill Shales at the head of Carrock Beck and south-east of High Pike have been found to be penetrated by a number of felsitic veins and strings which represent the eastward attenuation of a mass of porphyritic felsite which lies on the northern margin of the granophyre-gabbro mass of Great Lingy. The intense kaolinization which the shales have locally undergone appears to be connected with the intrusion of this felsite.

Carboniferous Limestone Series.—In the area of Lower Carboniferous rocks mapped by Mr. Hollingworth east of the Caldew the principal point of interest is that the lower part of the sequence is mainly limestone divided by subordinate beds of shale, whereas the upper part is of typical Yoredale facies in which limestone, shale and sandstone alternate.

The lower part compares fairly closely with the sequence in West Cumberland. The lowest beds are not well exposed but have been proved in borings to be upwards of 400 ft. thick. The Bryozoa limestone at the top of the Seminula Zone (i.e. the top of the 7th Limestone of West Cumberland) has been found west of Hutton Roof, and beds containing *Lithostrotion aranea* at the horizon of the 5th Limestone are found near Hegglehead. The overlying pale-grey, creamy-white and pseudobrecciated limestones, which represent the lower part of the 4th Limestone, appear as lines of crags and alternating griked dip-slope surfaces around Scales, and are traceable by Hutton Roof and Thwaite Hall towards Haltcliff Bridge. They also outcrop near Hudscales where they yield a typical D_1 fauna with *Cyathophyllum murchisoni*, *Lonsdaleia crassiconis*, *Chonetes comoides*, *Cyrtina septosa*, *Daviesiella llangollensis* and *Productus maximus*.

The lower part of the upper beds is exposed in Gillcambon Beck and its tributaries between Wharton House and Millhouse. Here sandstones predominate in some 500 ft. or so of strata which includes subordinate shales and two thick limestones. The lower of these is upwards of 50 ft. thick and is a medium-grey limestone which possesses a characteristic blotchy red-stained top and passes down into massive sandstone. The higher limestone, 60–70 ft. thick, contains *Saccammina carteri* and is underlain by a thin coal with fireclays and ganisters. It may be correlated with the Jew Limestone of the Westmorland Pennines. These beds are again exposed on the hillside west of Howhill where they are followed by a group of limestones, sandstones and shales which may be tentatively correlated with the beds from the Tyne Bottom to the Four Fathom Limestone in the Yoredale sequence of the northern Pennines.

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Dr. Trotter has been engaged principally in re-surveying the Carboniferous Limestone Series in the neighbourhood of Caldbeck.

The prevalent trend of the faults, many of which are of considerable magnitude, is north-westward, but the presence of a second group of south-west trend gives rise, in places, to block faulting.

It has been found that the beds up to the top of the lower Dibunophyllum Zone (D_1) closely resemble those of the corresponding sequence in West Cumberland and the nomenclature in use in that area has been provisionally adopted for the Caldbeck area.

The upper part of the 7th Limestone including the Bryozoa Band at the top of the upper Seminula Zone (S_3) has been recognised east of Uldale, but the overlying strata up to the next limestone are poorly exposed. They contain, however, a thin coal, as well as sandstone and shale. The overlying limestone yields a D_1 faunal assemblage including *Lithostrotion junceum* (Flem.), *Productus corrugato-hemisphericus* Vaughan and *P. maximus* M'Coy. It is characterized at Caldbeck and Uldale by an extensive development of black chert. The limestone is probably equivalent to the 6th of West Cumberland, from which, however, no cherts have been recorded.

The overlying limestone yields a fauna similar to that of the 5th Limestone of West Cumberland, including such characteristic forms, recognized by Mr. C. Edmonds, as *Lonsdaleia duplicata* Mart. mut. *melmerbiensis* Smith, and cf. *Lithostrotion aranea* Phill.

The sequence above the D_1 Zone up to the base of the Upper Limestone Group (*i.e.* to the Great Limestone) is well exposed on Faulds Brow. It consists of alternating beds of sandstone, limestone and shale which are strictly comparable to the Yoredale sequence of the Alston Block and the Yorkshire dales, and many of the characteristics, lithological as well as faunal, of the individual limestones of those areas have been found in the corresponding limestones of the Caldbeck district. For example, the Caldbeck equivalents of the Jew and Tyne Bottom Limestones are crowded with *Saccammina carteri* Brady, and the former limestone contains *Productus pugilis*. Again the limestone at the horizon of the Four Fathom or Undersett Limestone contains cherts, and the equivalent of the overlying Great Limestone yields *Lonsdaleia floriformis* (Mart.) mut. *laticlavia* S. Smith.

Coal Measures.—During this field season Mr. Eastwood completed the mapping of that portion of the Cumberland coalfield between Aspatria and Bolton New Houses, and the re-survey will result in considerable modifications. Apart from the insertion of lines and formations not hitherto shown—such as the outcrops of coals and the Whitehaven Sandstone Series, which render the structure more easily discernible—the chief alterations are due to a greater knowledge of the faulting. For instance, the Maryport Fault, shown as forming the northern boundary of the exposed

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coalfield, was originally regarded as a dominant structure giving a great downthrow to the north-north-west and bringing in the St. Bees Sandstone along its entire length. It is now known that this fault is nowhere of great throw, seldom exceeding 200 ft., while it certainly dies out to the east of Brayton Hall. On the other hand, faults of north-west trend become more prominent. Some attain throws of several hundreds of feet and repeatedly step the outcrop of the basal beds of the New Red Sandstone Series.

The country is heavily drift-covered and for much of our information we are dependent on mining and boring. The more important mines are situated to the west and comprise Oughterside and the Brayton Domain pits near Aspatria. Farther east lie the recently abandoned Baggrow and Allhallows pits and the older Bolton and Crummock collieries.

There has been noted in previous 'Summaries' a marked and rather rapid deterioration in the coals due to thinning and splitting of most of the seams on leaving the Bullgill area (Sheet 22) until, about Aspatria, the Yard Band is practically the only seam of value. Fortunately that coal is there a seam of excellent quality up to 5 ft. in thickness, and there can be little doubt that it (misnamed, however, as the Main Band) was worked extensively beyond Baggrow and Mealsgate.

A little of the Thirty Inch (representing the highest part of the Main Band of West Cumberland) and some Ten-quarters Coal has also been raised, but all the seams below the Yard Band may be regarded as worthless.

One important result of the field work is to show that the Master and Crow Bands (4–5 ft. and 2–3 ft. thick respectively) of the area north-east of Allhallows, which were considered by the late J. D. Kendall[1] to belong to the Whitehaven Sandstone Series, are undoubtedly situated in the upper part of the Productive Measures.

In this area Pow Gill, from its junction with the River Waver south of Wigton, provides excellent sections from some distance up in the Whitehaven Sandstone to near the base of the Productive Measures which include the Yard Band and Upper Three-quarters. These prove conclusively that the base of the Whitehaven Sandstone must be drawn considerably above the Crow Band. It is true that two thick sandstones occur below the Master Band, but these as well as the rest of the strata are typical Productive Measures. The presence of a mussel bed between the above-mentioned sandstones similar in all respects to that of West Cumberland, and occurring a little above the Yard Band, furnishes a reliable datum, and we have little or no doubt that the Master and Crow Bands occur somewhere about the Ten-quarters horizon.

BERNARD SMITH.

[1] 'The Structure of the Cumberland Coalfield,' *Trans. N. of Eng. Inst. Min. and Mech. Eng.*, vol. xxxii, 1883, p. 344. See also 'The Whitehaven Sandstone Series,' *Trans. Inst. Min. Eng.*, vol. x (1895-6) 1896, pp. 202-224.

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6. NORTHUMBERLAND AND DURHAM DISTRICT

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IN Northumberland the revision of the Lower Carboniferous rocks of one-inch Sheet 8 was continued by Mr. Anderson around Elsdon: later in the season Mr. Fowler (otherwise engaged on indoor map and memoir work for Sheets 9 and 10) spent a few weeks on ground farther west, near Falstone. In the early summer Mr. Eyles was transferred from Edinburgh and began a Coal Measure revision in Sheet 14, south of Morpeth. Mr. Burnett, though primarily occupied with Cheviot memoir work in the office, examined several borings round Newcastle, notes on which are appended.

Scremerston Coals.—Mr. Anderson reports that the lowest beds of this series rest on Fell Sandstones in Billsmoor Park, on the east side of which two coals have been wrought, with a third (said to be 4 ft. thick) farther north, near the Swindon Fault. All these beds are undoubtedly in the Scremerston Group, but above comes over 600 ft. of strata whose true position is not yet settled. Crinoidal limestones are common here, 7 or 8 being known, beginning with the Redesdale Limestone at the bottom, and all are quite certainly below the Woodend Limestone: these beds are of some economic importance since they contain the Fourlaws Coal, a 4-ft. seam in good state round Elsdon, where it has been wrought in many detached areas, separated by folding and step-faulting. One of the chief stratigraphical problems in this Sheet will be to account for the presence of such an important calcareous series in what appears to be the upper part of the Scremerston measures. Throughout the northern districts the upper limit of the Group has always been drawn at the Dun Limestone, the first below the Woodend. A continuation of that practice in Sheet 8, therefore, would remove a long sequence of limestone-bearing strata into the Scremerston Group.

The relatively sudden appearance of these beds around Elsdon may possibly be due to the dying-out of an unconformity, hitherto unsuspected, which cuts them out in more northern areas. In the meantime one is more inclined to ascribe it to the rapid oncoming of marine conditions as the Pennine district is approached.

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Mr. Fowler notes that the Plashetts Coal, so long wrought round Falstone, lies well down in the Scremerston measures. There are good exposures in the Falstone Burn, where an old mine, recently reopened, shows from 3 ft. 6 in. to 4 ft. 3 in. of coal. There is a characteristic roof to this seam, showing 4 in. of black 'bat' covered by 4 in. of inferior oil-shale, full of ostracods and fish-remains. About 10 ft. higher these recur and are accompanied by a rich and varied fauna of marine lamellibranchs: *Pteronites*, *Nuculana* and *Aviculopecten* were found, along with other genera. The Plashetts-Dun Limestone lies some way above this, and still higher is the 11-ft. Piper's Cross Limestone, much quarried locally. A 'bryozoa bed,' with *Fenestella* and *Stenopora* cf. *redesdalensis* Lee, was found south of Slaty Ford: the exact horizon is not yet determined.

Lower Limestone Group.—Mr. Anderson has been able to identify the Oxford and Woodend Limestones at many points in the Elsdon district, and several alterations to the mapping have resulted. The Oxford Limestone, normally developed, has been noted at Birkyburn, Ottercops, Whaup Moss, in the Ottercops Burn south-east of the farm, and in the stream south-east of Raechester. Two pale brecciated limestones below the Oxford are well seen at Ottercops and on an anticline east of Whaup Moss. Irregular rusty-coloured veinlets are common in both, but in a lower limestone, otherwise similar, are dark grey: this latter stone, lying about 100 ft. above the Woodend, probably represents the Watchlaw Limestone of the Belford—Berwick area.

The Woodend Limestone, in every way comparable to the well-known section at Hobberlaw, near Alnwick, can be seen on either side of the Otterburn—Newcastle main road 1 mile south-east of Raylees, and again west of Birkyburn, where it is faulted close up against the Oxford.

Coal Measures.—Mr. Eyles, during his first revision work south of Morpeth, attended a pit-sinking 600 yds. north-west of Clifton, west of the main road to Newcastle. Plant-remains and lamellibranchs were noticed, though too late to get a more exact location than that they were between 8 and 22 fathoms above the Brockwell Coal. Dr. Crookall was able to identify such plants as *Alethopteris lonchitica* (Schloth.), *Mariopteris nervosa* (Brongt.), *Calamites suckowi* Brongt. and *Lepidodendron ophiurus* Brongt., while Mr. Pringle referred most of the shell-fragments to *Anthracomya adamsi* Salter. All these fossils agree with a position low down in the Coal Measures.

Several core-borings in the Newcastle district were examined by Mr. Burnett. The Preston bore, west of Cullercoats, started in somewhat doubtful ground, but in its progress the position of the Beaumont Coal was identified through the discovery of the

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'Hopkins Shell-Bed,'[1] a local datum-line recognizable by the sequence of the fossils, rather than by any peculiarity in the shells themselves, which are all of long range. Such a 'mark' has to be used with care, as was illustrated in the three recent borings on the Ravensworth estate, south-west of Newcastle. These all passed through much the same strata, the seams ranging from the Five-Quarter down through the Beaumont-Busty group to the Brockwell. The 'Hopkins Shell-Bed' was got in one bore only, that at Silver Hill Wood (west of Park Farm) the others showing barren sandy strata at this position. At the same time rapid alternations of *Carbonicola*, *Naiadites*, and ostracod layers were noticed a few fathoms below the Main Coal, and there was a *Carbonicola*-ostracod bed over the Brockwell seam: in both cases conditions differed, but not widely so, from those in the 'Hopkins Shell-Bed.' In another band, got in the bore at Park Farm, 78 ft. below the Brockwell, the *Carbonicola* was a much larger species, akin to Dr. Trueman's *C. pseudorobusta*. The presence of Pecopterids in the roof of the Bottom Busty Coal in all three bores may perhaps be of some use in future correlations. In general, plants were fairly common above this position, but rare below; they were all of Yorkian facies.

Glacial.—Mr. Anderson reports that the prevalent glaciation in the Elsdon district was all from the west; occasional boulders of Cheviot rocks on the hills north-east of the village are no doubt incorporations of an earlier flow from the north. Of late-Glacial phenomena, the great Billsmoor Park—Hudspeth overflow channel has already been well described by Dr. J. A. Smythe[2]: no others were observed.

A point of special interest was noticed by Mr. Eyles in the low country between Choppington and Sleekburn. A widespread deposit of dark laminated clay, with occasional sandy films, rarely showing any distortion, is worked here in several large open pits: it is covered by a reddish-brown boulder-clay, with comparatively few stones, large ones being very rare. A particularly good section is seen in the Sleekburn clay-pit, where 4 or 5 ft. of boulder-clay covers 10 to 15 ft. of laminated clay, whose base is not seen. The boulder-content and the undisturbed state of the clays beneath leave little doubt that the cover belongs to the Upper Boulder Clay of Northumberland. This suggests that the laminated clays are a locally expanded representative of the gravel, sand and laminated clay parting elsewhere general between the two Boulder Clays. Farther west the laminated clays are replaced by current-bedded but quite undisturbed sands, well seen in a pit 1 mile south-south-east of Netherton, where they are covered by 3 ft. of reddish boulder-

[1] Hopkins, W., 'Further Modifications of the Correlation of the Coal-seams of the Northumberland and Durham Coalfield,' *Trans. Inst. Min. Eng.*, vol. lxxiv, Part 4, 1928, pp. 221–241. The author gives the essential characters of this Shell-Bed as:—"(1) An upper part consisting of *Carbonicola* shells only; (2) A middle part consisting of numerous *Spirorbis*, with *Carbonicola*, *Naiadites*, and a few ostracods; and (3) a basal part consisting of ostracods only."

[2] Smythe, J. A., *Trans. Nat. Hist. Soc. Northumberland, etc.*, vol. iv, 1914, p. 106.

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clay. The mass of 'dead ice,' whose enclosed detritus provided the material for the Upper Boulder Clay, seems to have floated on an extensive sheet of water in which the laminated clays and sands accumulated, but how such a body of water was held up is not yet clear.

R. G. CARRUTHERS.

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(B)—SCOTLAND

1. AYRSHIRE, RENFREWSHIRE AND DUMBARTONSHIRE

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FIELD WORK was carried out by this unit in three areas—in one-inch Sheet 15 near New Cumnock, Ayrshire, in one-inch Sheets 29 and 30 south of Gourock, Renfrewshire, and in one-inch Sheet 30 in the Kilpatrick Hills and in the neighbourhood of Helensburgh, Dumbartonshire.

AYRSHIRE

Mr. Simpson revised an area of Old Red Sandstone and Carboniferous rocks near New Cumnock.

Hillend Knowe, beside the farm of Corsencone, three miles east of New Cumnock is formed of agglomerate largely composed of basalt of Lower Old Red Sandstone age. Piercing the agglomerate is a small intrusion of acid porphyrite, a common type among the igneous rocks of this period.

At or near the base of the Upper Old Red Sandstone a thick cornstone occurs over an extended area. In the Guelt Water, 2 miles north-east of Craigdullyeart, the cornstone rests on basalt lava of Lower Old Red Sandstone age. The succeeding strata comprise for the most part white or yellow pebbly sandstones.

A complete section of the Lower Limestone Group is exposed in the Glenmore Water at Dalblair, 4 miles north of New Cumnock. In the stream half a mile east of Dalblair the Hurlet Limestone is followed by approximately 100 feet of sandy unfossiliferous beds. These are succeeded by 4 feet of blaes with highly fossiliferous ironstone bands over which is a limestone, 10 to 15 ft. in thickness, which may be correlated with the McDonald Limestone of Muirkirk. This limestone is exposed at the confluence of the Glenmore and Guelt Waters. Two feet above it is a highly fossiliferous band of sandy limestone six inches thick, the top of the Lower Limestone Group.

In the one-inch geological Sheet 15 published in 1870 the boundary between the Carboniferous and the Silurian and Ordovician rocks south of New Cumnock is shown as a fault. Stream sections in this area clearly show that the Carboniferous is not faulted against the older rocks, but unconformably overlies them. In the Burnton

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Burn at a point 300 yds. downstream from Burntonhill a band of conglomerate 2 ft. thick with pebbles of chert and coal fragments rests on Silurian grit. The Carboniferous strata, which are of Limestone Coal Group age, dip off the Silurian rocks at a moderate angle.

In many fine sections in the Glenmore and Guelt Waters east of Dalblair two boulder-clays separated by a deposit of sand and gravel are clearly indicated. The lower boulder-clay, which extends to 900 ft. above O.D., is dark brown or greyish-black in colour, and carries numerous fragments of recent marine shells and occasional boulders of the distinctive New Red Sandstone of the Mauchline Basin. Resting upon it are rudely stratified sands and fine gravels, 30 ft. thick in some sections, and close at hand dwindling to a few inches. Occasional shells are also to be noted in this deposit. Above the sand and gravel is another boulder-clay light brown in colour, very sandy in texture with erratics of greywacke and chert and shell fragments. The lower boulder-clay is clearly the product of ice moving inland from the west. The upper boulder-clay was laid down by ice moving westwards off the Southern Uplands, after an interval when the sand and gravels were deposited.

Renfrewshire

The district revised by Mr. A. G. MacGregor and Mr. Kennedy lies along the boundary of one-inch Sheets 29 and 30, and includes the country around Inverkip and Gourock and the upper reaches of the Noddsdale Water. This area is occupied by sediments of Upper Old Red Sandstone and Calciferous Sandstone age, and by lavas belonging to the Carboniferous volcanic plateau that forms the western boundary of the coal and limestone district around Johnstone (Sheet 30).

The revision has confirmed the main structural features indicated on the published one-inch geological maps (Sheet 29, 1892; Sheet 30, 1878). The Carboniferous lavas forming the high ground south of Gourock occupy the centre of a shallow syncline with a general east-and-west trend. The Calciferous Sandstone sediments outcrop to the north and south of this syncline, and in the centre of a smaller elongated synclinal fold that extends south-south-westward from Loch Thom to Outerwards (Sheet 30). The main outcrop of Upper Old Red Sandstone occupies the core of the anticline separating these two synclines.

In the absence of fossil evidence the separation of the Upper Old Red Sandstone from the basal Carboniferous sediments presents great difficulties. To the south, at Fairlie (Sheet 21) and at Largs (Sheet 29), yellow sandstones underlie the Carboniferous lavas and pass down into a thick development of brick-red pebbly sandstones. Neither cornstones nor beds of Ballagan type are present, and the whole series is referred to the Upper Old Red Sandstone. Farther north, in the Outerwards and Inverkip—Loch Thom districts,

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brick-red pebbly sandstones are succeeded by yellow limy sandstones and marls with thick cornstones (Upper Old Red Sandstone facies), followed by green shales with thin cementstone bands (Ballagan facies). Over most of the area, however, the shales and cementstones are in turn overlain by limy sandstones, red marls, and cornstones, while locally the two facies succeed each other repeatedly, as for example along the shore between Gourock and Cloch Point. We thus have interbanding of types of sediment that have until recently been regarded as typical Upper Old Red Sandstone and Calciferous Sandstone (Ballagan) facies respectively.[1]

North of Outerwards, near Knockencorsan, sediments of Ballagan type are succeeded by yellow sandstones and these in turn by bedded ash on which rest the basal flows of the Carboniferous lavas. The lavas are almost all mugearites, basaltic mugearites, or Markle basalts, and these types are everywhere interbedded. On Dunrod Hill, west of Loch Thom, and elsewhere, composite lava flows are locally well exposed in scarp features. The upper part of each such flow consists of highly porphyritic Markle basalt, and the lower of non-porphyritic basaltic mugearite. When traced laterally a particular flow may become wholly porphyritic or wholly non-porphyritic.

A number of sheets and a few dykes of acid quartz-bearing trachytic rocks, with phenocrysts of acid plagioclase, have been intruded into the Upper Old Red Sandstone and Carboniferous sediments. Many decomposed basaltic dykes of late Calciferous Sandstone age cut the sediments and the overlying lavas. Composite examples have been found, with non-porphyritic marginal bands and a central portion containing felspar phenocrysts. An ash neck on Knockencorsan is associated with basalt intrusions, and probably supplied the bedded ash that locally underlies the lavas.

DUMBARTONSHIRE

Mr. Simpson continued work on the northern slopes of the Kilpatrick Hills, and also surveyed a small area near Helensburgh.

In the published one-inch geological map of Sheet 30 a conglomerate of Upper Old Red Sandstone age occupies the peninsula of Ardmore, 2 miles south-east of Helensburgh. This is only partly correct. There are present here two conglomerates, excellently exposed, of Lower and Upper Old Red Sandstone age respectively, separated by a well-marked unconformity.

The contents of the Lower Old Red conglomerate comprise moderately-sized, rolled boulders of vein quartz, quartzite, phyllite, porphyrite and andesite, set in a dull brown matrix. The Upper Old Red Sandstone conglomerate differs from that of the Lower Old Red Sandstone in the absence of boulders of andesite, in the greater angularity of the vein quartz, and in the colour of the matrix.

[1] *Cf.*, Richey, J. E., in 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 90

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The latter is a bright brick-red, which contrasts vividly with the dull brown tint of the Lower Old Red.

Seven, hitherto unmapped, volcanic necks of Calciferous Sandstone age were located in the Kilpatrick Hills east of Bonhill. In the majority of cases the vent agglomerate is accompanied by an intrusion, generally basalt of Jedburgh type. In two instances within the area surveyed other varieties of basalt have been found. Knockupple, on Dumbarton Muir, 4 miles east of Bonhill, has a plug of beautifully fresh basalt of Dunsapie type. At Knockshanoch, 1½ miles west of Knockupple, the intrusion is a rock with the groundmass of a basalt of Dalmeny type and large phenocrysts of olivine.

E. B. BAILEY.

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2. FIFE

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J. KNOX, B.Sc. } Geologists.

ON their return from the Shetlands, Messrs. Haldane, Allan and Knox continued revision work in Fife. Messrs. Haldane and Allan completed their mapping around North Queensferry and Inverkeithing, and between Burntisland and Auchtertool respectively, thus concluding the survey of the area to be described in the first two of the economic memoirs dealing with the Fifeshire coalfield. Mr. Knox continued his investigation of the Dysart-Leslie area northward to Falkland.

Calciferous Sandstone Sediments.—In the Burntisland district, the beds from the Burdiehouse Limestone up to the horizon of the Houston Coal are known in detail from borings and natural sections, but of the strata below the Burdiehouse little information has so far been available.[1] In 1928, however, a boring for water was put down by the British Aluminium Co. at their works a little west of Kirkton, Burntisland, and permission to examine the cores was kindly given by the manager, Mr. W. E. Sims. The boring started about 40 fathoms below the Burdiehouse Limestone and continued to a depth of 400 ft. The strata proved are very poorly exposed on the coast between Colinswell and Burntisland and the information obtained by a detailed examination of the cores has added considerably to our knowledge of the succession in the lower part of the Oil-Shale Group in the Burntisland district. The only oil-shale recorded was an 18-in. brown shale at a depth of 367½ ft. At 146 ft. occurred 2 ft. of blaes containing *Orthoceras* and *Beyrichoceratoides* cf. *truncatum* (Phill.). The occurrence of the latter fossil is of interest as it is identical with the shell recorded as *Glyphioceras truncatum* (Phill.) from the marine band in the Fordel railway cutting and on the shore at Seafield, St. Davids. The Fordel and Seafield marine band has hitherto been tentatively correlated with the Raeburn shell-bed of the Lothians,[2] but careful search of the shore section between Seafield Cottage and the lavas exposed in the core of the anticline at Charles Hill and Barnhill Bay has failed to reveal any trace of the Burdiehouse Limestone. The Seafield marine band, therefore, possibly occupies a much lower stratigraphical

[1] 'Oil-Shales of the Lothians' (*Mem. Geol. Surv.*), 3rd edit., 1927, pp. 95–99.
[2] *Ibid.*, p. 99.

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GENERALIZED SECTION along coast from WEST WEMYSS to DYSART.

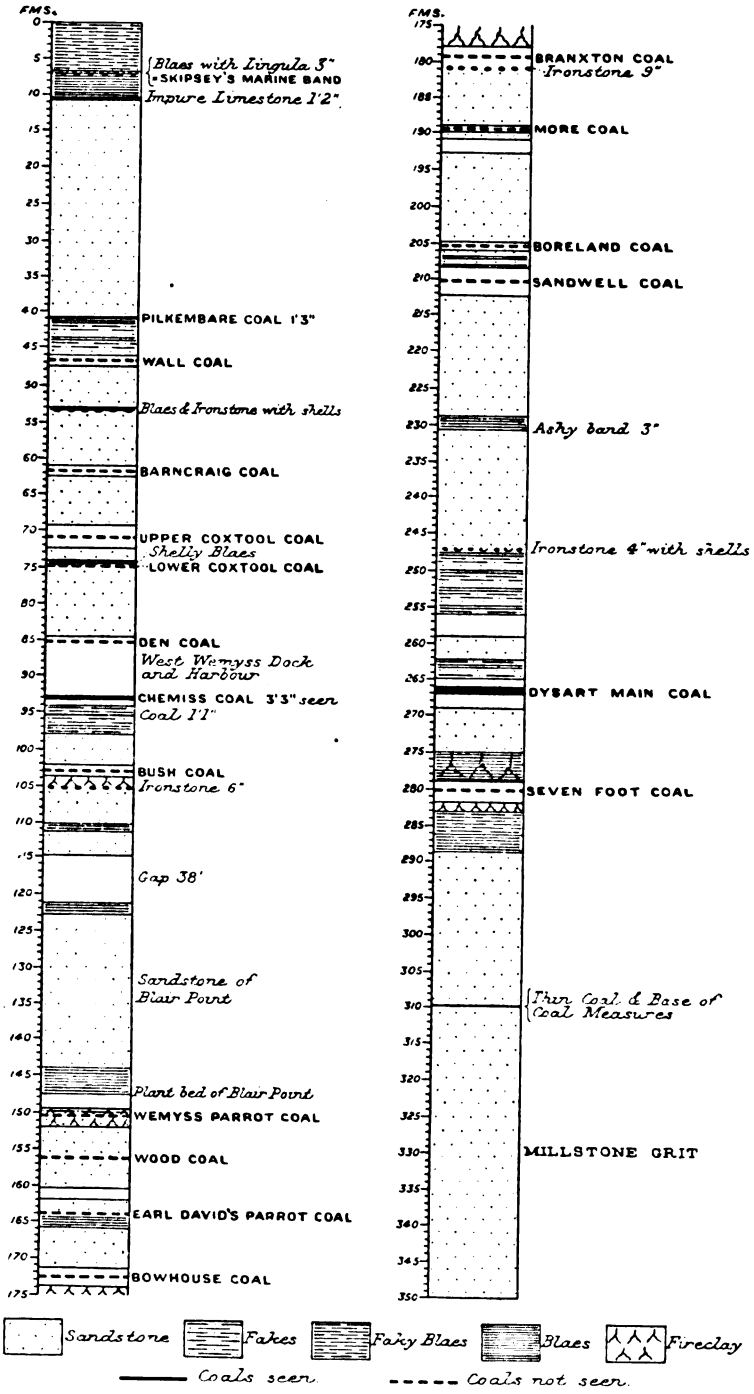

FIG. 7.

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horizon well below the Burdiehouse Limestone, and may be the equivalent of the marine band of the Kirkton bore. No trace of the Pumpherston Shales was obtained in the boring, but the Kirkton marine horizon must be very near the position of the Pumpherston shell-bed of the Lothians.

Coal Measures.—The accompanying Vertical Section (Fig. 7) is constructed from detailed measurements made by Mr. Knox along the Fifeshire coast from the base of the Barren Red Measures opposite Wemyss Castle in a south-westerly direction to the top of the Millstone Grit which forms the rocky part of the shore between Dysart and Pathhead (east of Kirkcaldy). The length of coast-line represented by the section measures about 3 miles, along the greater part of which the strata are fully exposed. Few of the coals, however, are now actually seen, but their position in various gaps in the sequence has been fixed by comparing the succession on the shore with bores and pit-sections adjacent to the coast.

The marine band at 7 fms. has yielded to Kirkby: "Specimens of crinoid stems, *Lingula, Discina, Productus semireticulatus, Aclisina* (*Murchisonia*) *striatula, Bellerophon Urei, Orthoceras* and *Discites*, together with various fishes."[1]

From the shelly band at 74 fms, *Carbonicola aquilina* (J. de C. Sow.), *Carbonicola similis* (Brown) and *Naiadites carinata* (J. de C. Sow.) have been obtained. The other shelly horizon, at 247 fms., is poorly exposed on the coast, but it is undoubtedly the same band as that seen in the quarry at the Gallatown Brick Works, 1 mile to the north, where abundant remains of *Carbonicola robusta* are found. These fossils have been determined by Mr. Pringle, who states that the fauna from the shelly band at 74 fms. suggests a position in the Similis Zone of Davies and Trueman's classification.

Igneous Intrusions.—The great quartz-dolerite sills at North Queensferry have been shown by Mr. Haldane to be affected by several west-north-west faults. At two localities vertical chilled junctions against sediments have been noted, which show that the sills were to some extent intruded transgressively. One of these junctions is seen at Limpet Ness, the other in a railway cutting near the railway pier at North Queensferry.

South of Falkland, the East Lomond Hill has been mapped by Mr. Knox, who has confirmed Dr. Walker's[2] reinterpretation of the olivine-dolerite of the summit as a vent-intrusion associated with basic ash and agglomerate.

J. E. RICHEY.

[1] See 'Geology of Central and Western Fife and Kinross' (*Mem. Geol. Surv.*), 1900, p. 147.
[2] Walker, F., 'The Igneous Intrusions between St. Andrews and Loch Leven,' *Trans. Roy. Soc. Edinburgh*, vol. lvi, pt. i, 1928, pp. 5–6.

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3. ORKNEY ISLANDS

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THE Geological Survey mapping of the Orkney Islands was completed during the past field season, and the indoor work in connexion with the preparation of the maps and memoir is now in progress.

Mr. Wilson surveyed Westray, Papa Westray and Rousay; Mr. Stephens the north part of Hoy, Risa and Cava; Mr. Edwards the south of Hoy with Fara, Walls and Flotta. The mapping of Stronsay, Shapinsay, Egilsay and Viera was done by Mr. Jones.

Stromness Flags.—In the north of Hoy Mr. Stephens has been unable to detect any trace of the well-known fish bed of the West Mainland. He also finds it impossible to determine whether any of the flags, which form an almost unbroken sequence along the north coast as far as the Kame of Hoy, are of Rousay age.

Rousay Flags.—Two small faulted patches of flags exposed at Quoyness in the north of Hoy are assigned to the top of the Rousay beds. They are overlain by the well-known Lower Eday Sandstone.

In the south of Hoy Mr. Edwards finds that the fault which separates the Rousay Flags on the east from the Upper Old Red Sandstone on the west is reversed. Good exposures occur at Risa Sound and on the south coast near Wetter Hill. The base of the group is not seen, but in the west of Walls near Lythes and in the south of Hoy the Rousay Flags pass up into the Lower Eday Sandstone. An *Estheria membranacea* bed, found by Mr. Strachan, near Lythes is probably the highest in the group. The work of Mr. Jones shows that the islands of Egilsay and Viera consist entirely of rocks of Rousay age. A belt of highly disturbed strata which follows the west coast of Egilsay is probably continuous with the fault which forms the eastern boundary of Scapa Flow, and with the wide zone of broken strata which crosses Westray from the Bay of Tafts to Rackwick.

Rousay beds form almost the whole of the north-west part of Shapinsay, and are separated from the Eday beds by a fault which runs from near Luffaness to the Bay of Linton. The fish bed which contains the small form of *Dipterus valencienesii*, that occurs near the top of the Rousay Flags, has been obtained south of Odin Ness and north of Lamb Head.

The islands of Rousay, Westray and Papa Westray appear to consist entirely of rocks of Rousay age. With the exception of a

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small area in the west of Rousay near Fishing Geo, where the top of the Stromness beds may be exposed about low-water mark, neither the top nor the base of the group is seen in any of the islands. *Coccosteus minor* has been noted at several localities. Fragments only occur in two bands of purple flags, about 25 ft. apart, which are exposed in the steep bank on the north-east of Noup Head in Westray. In the north of Papa Westray three hard limy bands are present in about 100 ft. of strata. The two lower ones yield abundant remains of *C. minor* and other fish. Good exposures occur near Munger House, at Mull Head and north of Foul Craig.

The mapping of Rousay has tended to show that the *C. minor* bed noted by Sir J. S. Flett [1] at Sacquoy Head occurs at least 1,300 ft. up in the Rousay beds. At that locality the fish bed is underlain by a pebbly sandstone which has been traced to a height of over 800 ft. on Blotchnie Fiold. On the beach at Viera Lodge near Hullion a thin band of limy sediment occurs from which Mr. Strachan has obtained *Estheria membranacea*. This is probably at the same horizon as a bed exposed in a small quarry at a height of about 340 ft., near the bend in the road half a mile north-east of North Howe. This locality is separated by a fault with a down-throw to the east from another Estheria bed, and from the already mentioned possible top of the Stromness beds at Fishing Geo.

Eday Beds.—Mr. Edwards finds that the general succession of the Eday beds in Walls and Flotta agrees with that in South Ronaldsay. The faulted nature of the ground, however, makes it impossible to measure the thickness with anything like accuracy. It can be stated that the Upper Eday Sandstone attains a thickness of over 1,700 ft. A bed with good fish-remains, that have not yet been determined, occurs on the east coast of Flotta between Quoy Ness and Lee Craig.

In Stronsay Mr. Jones has noted the occurrence of a thin band of flags with *Tristichopterus alatus* at a number of faulted localities.

Contemporaneous Igneous Rocks.—The small exposure of igneous rock exposed at Haco's Ness in Shapinsay was examined by Mr. Jones. It consists of a highly decomposed basic lava flow, contains numerous included fragments and veins of sandstone and is interbedded in the Eday Flags.

In Hoy a volcanic episode occurred in the period which elapsed between the folding and weathering of the Middle Old Red Sandstone and the deposition of the Upper Old Red Sandstone. The basal member is a fairly persistent bed of red ashy sediment which rests on an uneven surface of older rocks—Stromness beds at the Kame of Hoy, and Lower Eday Sandstone at Rackwick. It varies from a few feet up to 40 ft. in thickness. The overlying lava appears to consist of only one flow, which at the Kame of Hoy is nearly 400 ft. thick,

[1] Flett, Sir J. S., 'The Old Red Sandstone of the Orkneys,' *Trans. Roy. Soc. Edin.*, vol. xxxix, pt. ii, 1898, pp. 398–400.

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with columns up to 200 ft. in length in the central portion. The flow is very impersistent, and both at the Kame of Hoy and at Rackwick rapidly dies out to nothing.

Upper Old Red Sandstone.—At the Old Man of Hoy it can be seen that a certain amount of denudation of the volcanic zone preceded the deposition of the Upper Old Red Sandstone. The basal beds of the latter are found to be bedded against a protruding knob of lava, the upper surface of which shows distinct signs of erosion. The Upper Old Red Sandstone is restricted to Hoy and Risa and rests unconformably on the older rocks. It consists of upwards of 3,000 ft. of red, pink, yellow and white sandstone with interbedded bands of marl. A few crustacean-like tracks found by Mr. Stephens at Red Glen, Ward Hill, are about the only signs of life met with.

Intrusive Igneous Rocks.—A number of dykes have been mapped including three which cut the Upper Old Red Sandstone in Hoy. Several small volcanic vents have been noted in Hoy and Walls. They consist essentially of basic agglomerate. The one which forms the small hill known as The Witter in the north of Hoy contains also a basic plug. A small outstanding hill about three quarters of a mile to the S.S.W. is also most probably a plug, but its relations to the surrounding rocks are rather obscure, and it may possibly be a faulted outlier of the lava flow.

Recent Deposits.—A few small patches that appear to be Raised Beach have been noted by Mr. Stephens near Muckle Head in the north of Hoy. The deposit consists of cemented gravel, is from 10–15 ft. thick, and rests on a rock platform, which is about 25 ft. above sea level. As no higher beaches occur in Orkney it is considered probable that this material represents the pre-Glacial beach, which on the west of Scotland occurs at an average height of about 120 ft. If this supposition is correct it follows that Orkney has been depressed about 100 ft. more than the west coast since Glacial times. It would also appear that the numerous fragments of a rock platform at present sea level are remnants of the post-Glacial 100-ft. Raised Beach.

G. V. WILSON.

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4. SHETLAND ISLANDS

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J. PHEMISTER, M.A., D.Sc.
D. HALDANE, B.Sc. } Senior Geologists.
J. K. ALLAN, M.A., B.Sc.
J. KNOX, B.Sc. } Geologists.

FIELD WORK in Shetland was begun during the past summer by the above-named members of the staff. Dr. Read, Dr. Phemister and Mr. Allan were stationed in the northern islands of Unst, Fetlar and Yell respectively, Mr. Haldane in the Delting district of the North Mainland, and Mr. Knox at Lerwick.

Progress was made with the detailed mapping of the schists and Old Red Sandstone. Rock masses under investigation which are of more especial interest include: the ultrabasic and basic igneous rocks of Unst and Fetlar; a massive conglomerate associated with the schists of Fetlar; the granitic complex of the North Mainland; and breccias in the Old Red Sandstone near Lerwick.

UNST

Metamorphic Rocks.—Around Balta Sound, Unst, Dr. Read has mapped an area of the well-known ultrabasic and basic rocks made famous by the mineralogical researches of Heddle, and recently studied by Dr. F. C. Phillips.[1] The rocks include serpentine and greenstone, the latter term being used for metamorphosed or modified gabbros.

The base of the serpentine has been traced from Loch of Watlee northward to Loch of Cliff; below the serpentine are striped hornblende-schists, graphite-schists, limestones, mica-schists, and gneisses with staurolite, kyanite and garnet, which form the western and northern parts of Unst. Within the ultrabasic mass, many varieties of serpentine have been mapped, and preliminary microscopic investigation shows that these varieties depend upon mineralogical differences. The commonest consists of a yellow-weathering serpentine, dark green or black on fresh fractures, seen in slices to contain small olivine relics. This, the country rock of the Unst chromite deposits,[2] forms a great homogeneous body around Nikka Vord north of Balta Sound. Near Loch of Watlee, many bands of serpentines of different characters have been mapped, which run parallel to the base of the mass and are probably of sheet form. Towards the east, or top, of the ultrabasic body, pyroxene becomes an important constituent, and at the margin there occurs a broad belt of pyroxenite

[1] Phillips, F. C., 'The Serpentines and Associated Rocks and Minerals of the Shetland Islands,' *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927, pp. 622–652.

[2] 'Special Reports on the Mineral Resources of Great Britain, vol. v (2nd edit.), Potash-felspar,' (*Mem. Geol. Surv.*), 1917, pp. 33–35; F. C. Phillips, *loc. cit.*, pp. 634–637; C. S. Hitchen, 'Unst and its Chromite Deposits,' *Mining Magazine*, vol. xl, 1929, pp. 18–24.

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sometimes partly serpentinised or converted into tremolite-rock. This pyroxenite fades off into yellow-weathering olivine-serpentine to the west and north-west. Dyke-like bodies of similar pyroxenite occur, however, in the olivine-serpentine, as at Swinna Ness at the north entrance to Balta Sound. Narrow zones of schistose serpentine are of general occurrence, and run at right angles to the strike of the banding of the serpentine mass. These belts consist of black slate-like serpentines, pale green carbonate-talc-chlorite-schist and many other forms of sheared ultrabasic rocks.

The north end of the Unst greenstone has been mapped on the islands of Balta and Huney, and around Colvadale and over Virda Field in Unst. It consists of pale green or green and white rocks of variable grain, made up of decomposed felspar and a pale amphibole. Sometimes the structure of the original gabbro is preserved. In many places, however, the rock is converted into green schists along shear-belts. On Balta and elsewhere the greenstone is cut by very coarse greenstone-pegmatite veins with hornblende crystals up to 9 inches or more in size.

The junction of serpentine and greenstone can be accurately mapped, and there is evidence that the greenstone is the later intrusion. Further, on Balta and especially east of Longa Water, 2 miles south of Balta Sound, large masses of ultrabasic rock are found within the greenstone and are veined by it.

Fetlar

The southern half of Fetlar was surveyed by Dr. J. Phemister, and, as already known from the early work of Hibbert and Heddle, it contains a large number of rock-types. These conveniently fall into three groups; to the west, the Lamb Hoga Group; next, the Central Fetlar Group; to the east, the Funzie Conglomerate.

The Lamb Hoga Group consists of two horizons of pelitic gneiss separated by a broad belt of siliceous and semipelitic gneisses. The lower, eastern, pelitic horizon carries thin metamorphic limestones. Strings and lenses of granite interfolded with the pelitic gneisses, and later veins and sills of granite, pegmatite, quartz-muscovite-rock, and quartz, cutting both pelitic and siliceous gneisses, are evidence of widespread granitic injection. Preliminary microscopic examination shows the presence of staurolite, sillimanite and garnet in the pelitic gneisses. Kyanite has been found as large radiating aggregates. There is evidence of extensive retrogressive metamorphism characterized in the field by the development of muscovite and chlorite, which impart a distinctive scaly aspect to the Fetlar gneisses. Under the microscope is seen the conversion of staurolite and garnet to chlorite, and of sillimanite to aggregates of muscovite. Associated with this metamorphism is the development of porphyroblastic chloritoid which in one specimen measures nearly 2 cm. across. Tourmaline has been detected in the pelitic and siliceous gneisses and in the pegmatite and quartz-muscovite veins. Kaolin-

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isation of the siliceous gneiss has occurred in a belt 100 yds. wide at Moo Wick.

Between the Lamb Hoga peninsula and a line running from Strandburgh Ness to the Geo of Litlaland outcrops the Central Fetlar Group consisting of green, grey and black schistose, phyllitic and slaty rocks. These are intruded by serpentine and basic epidiorites and the whole assemblage is highly folded. Dips are usually nearly vertical and may be towards the east or west, and lines of crush and movement striking north are frequent. The sedimentary members of the group include graphitic schists or phyllites, well exposed on the coast south of Tresta, and chloritic schists or phyllites, best seen along the east and south-east coast of the Wick of Gruting. Many of these green rocks carry magnetite, usually as tiny octahedra concentrated along thin laminae but occasionally as scattered crystals up to a quarter of an inch across. Other varieties include hard compact siliceous types, softer slaty rocks and greasy talcose schists with quartz knots. Certain kinds of green schist carry feathery amphibole, and may be derived from epidiorites.

All the intrusive rocks so far found in the Central Group are greatly affected by pressure. The serpentines are very largely converted to talcose or carbonate rocks, and contain lenticular zones of dark green chloritic rock; while the epidioritic rocks are always well foliated and are frequently in the form of hornblende-schist. Both types of intrusive rock map as long lenticular sills, and it is noteworthy that thin zones of serpentine in the coast-section appear, when traced inland, to be offshoots of the main serpentine body. In how far this should be regarded as original apophysal intrusion is uncertain, since practically all the junctions of serpentine with the country rocks are obvious planes of movement.

The third group contains only one member, the Funzie Conglomerate. This immense conglomerate, cut off by the sea on the east, has an outcrop one mile wide and, since its dips are constantly westwards at angles of 35 to 50 degrees, it has a minimum thickness of 4,000 ft. Its importance as a stratigraphical unit is therefore of the first order, yet, since 1822, when Hibbert described it under the terms 'micaceous, talcose and chlorite schistus of a glandular and conglomerate structure,' no reference to it has been made by any of the geologists who have visited Fetlar. The western boundary of the conglomerate over most of its course appears to be a line of movement, as is particularly well seen at a junction with epidiorite on the east side of the Geo of Litlaland, where the conglomerate is so deformed that the pebbles and boulders are quite unrecognizable as such through a distance of about 20 yds. across the strike. In general the intensity of deformation diminishes eastward and northward. Intercalations of fine-grained material are rare, and the matrix of the conglomerate is correspondingly scanty. The minerals characteristic of the matrix and of the fine-grained bands are chlorite and epidote. Most of the boulders are of quartzite,

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mainly white and pure, but sometimes felspathic; a certain proportion are of granite and granulite which are always more deformed than the quartzites; less common and not easily recognized where deformation is considerable are others of green foliated and unfoliated basic rocks, many of which appear to be igneous. The latter are best seen at The Tind, about a mile north of Funzie Bay. There, one zone in the conglomerate contains 25 per cent. of basic boulders and is associated with a twenty-foot belt of schist unusually rich in chlorite and epidote.

YELL

North of Mid Yell, Mr. Allan has surveyed an area extending across the island from east to west. The rocks are mainly mica-schists and gneisses with some siliceous types and are in general steeply inclined to the west.

On the east coast, between Basta and Mid Yell Voes, a belt of mica-schist with small lenticular aggregates of quartz and garnet is followed by a more massive gneissose rock with many acid pegmatites. These latter send off innumerable ptygmatic veins. In the centre of the island, from the Hill of Basta to the Hill of Camb, the schists are flaggy, fine-grained semi-pelitic rocks. West of the Hill of Camb, they are considerably modified by abundant granitic and pegmatitic injections. The rocks everywhere contain garnets and the injected belts, more particularly to the east of Loch of Colvister, contain some sillimanite and tourmaline.

At the south end of Burra Ness occurs a series of pink and black gneisses with intrusive greenstones entirely different from the bulk of the Yell schists and gneisses.

Numerous small irregular intrusions of garnetiferous hornblende-schist have been noted.

MAINLAND, DELTING

The ground surveyed by Mr. Haldane comprises the northern half of the parish of Delting, and the islands in Yell Sound. The country rocks are siliceous, semi-pelitic and pelitic granulites, schists and gneisses, together with subordinate belts of limestone. The strike of the rocks changes from north to east as they are followed northward. In this direction, too, veins of pegmatite become abundant, and still farther north innumerable sheets and irregular masses of granite occur, until one third of the complex is formed of them.

Within the complex, the boundaries of which were mapped by Peach and Horne[1] during their investigation of the Shetlands, the country rocks have undergone considerable injection-metamorphism. Sillimanite and garnet are abundant, and numerous rocks of mixed parentage are produced. Intrusive igneous rocks of earlier date than the general metamorphism are represented throughout the area by small masses of garnetiferous amphibolite and hornblende-schist,

[1] Peach, B. N., and J. Horne, 'The Glaciation of the Shetland Isles,' *Quart. Journ. Geol. Soc.*, vol. xxxv, 1879, pp. 782–3.

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and these undergo extensive metamorphism within the injection-complex.

Lerwick, Bressay and Noss

Old Red Sandstone.—The survey of the Old Red Sandstone of the Lerwick district, including the islands of Bressay and Noss, was completed by Mr. Knox. The sequence established by Peach and Horne [1] and accepted later by Dr. Finlay [2] is, in descending order, as follows :—

		Ft.
Bressay Flagstones	at least	5,500
Lerwick Sandstone	,, ,,	3,500
Rova Head Conglomerate	,, ,,	2,500
Brindister Flagstones	,, ,,	2,000
Basement Breccia	up to	200
Total thickness, at least		13,500

The thicknesses stated were estimated by Mr. Knox. The general structure of the area is a broad syncline with easterly pitch, which is considerably complicated on the Mainland by faulting.

In the north of Bressay, a conglomerate about 80 ft. thick is succeeded by some 5,500 ft. of Bressay Flags, and may represent a transition series between the Lerwick Sandstone and the Flags.

Remarkable breccias were discovered in Bressay and Noss by Peach and Horne who described them as volcanic necks. They have also been investigated by Dr. Finlay who attributed them to movement initiated by faulting. Several additional outcrops have now been located, and further information concerning their mode of occurrence is available. They consist of angular fragments of country rock, i.e., sandstones and flagstones of types found *in situ* in the immediate vicinity. The fragments are set in a finely comminuted matrix of the same materials, and vary in size up to blocks five feet across. The breccias show no traces of bedding, or slickensiding. They occur, with few exceptions, in two broad north-south belts of intense disturbance ; one, on the west side of Bressay, extending from Ness of Beosetter southward for 3½ miles ; the other, along the east coast of Bressay and the western extremity of Noss. There is a marked increase in the number of fault-fractures wherever the breccias are found.

In the western belt, round Leira Ness and the Bight of Ham, breccia is met with in a number of apparently disconnected areas separated by large masses of unbroken rock 100 yds. or more in length. The latter are usually disposed with their strike approximately north and south, their bedding is either vertical or inclined steeply to the west. The dips of the country rock bounding the

[1] Peach, B. N., and J. Horne, 'The Old Red Sandstone of Shetland,' *Proc. Roy. Phys. Soc. Edinburgh*, vol. v, 1880, p. 82 ; and 'The Glaciation of the Shetland Isles,' *Quart. Journ. Geol. Soc.*, vol. xxxv, 1879, p. 784.

[2] Finlay, T. M., 'The Old Red Sandstone of Shetland. Part I. South-Eastern Area,' *Trans. Roy. Soc. Edinburgh*, vol. liv, 1926, p. 555.

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belt are on the other hand, at low angles and are directed mainly to the south-east or south. The junctions between the breccias and the intervening masses are usually clean-cut, but in certain cases a gradation from one to the other is observed. These facts suggest a common origin for both but no satisfactory explanation of the phenomena has yet been advanced.

J. E. RICHEY.

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III. SECTIONAL REPORTS

1.—PALAEONTOLOGICAL DEPARTMENT

In London

F. L. KITCHIN, Sc.D., PH.D., F.R.S., Palaeontologist (District Geologist).
C. P. CHATWIN, M.Sc., Assistant-Palaeontologist (Senior Geologist).
C. J. STUBBLEFIELD, PH.D., A.R.C.Sc., Geologist.

In Edinburgh

J. PRINGLE, Assistant-Palaeontologist (Senior Geologist).

A. ENGLAND AND WALES

Much routine work has been done in connexion with current surveying and the preparation of memoirs. The results will be incorporated in the published memoirs in due course, and there is little of outstanding interest that can be fittingly reported here.

During July Dr. C. J. Stubblefield visited various outcrops of the Lower Palaeozoic rocks now being surveyed in Shropshire and Montgomeryshire. He has been able to prove the presence of Middle Cambrian beds in the area immediately north of the Lawley Hill, and of two fossiliferous horizons in the Dolgelly Stage of the Upper Cambrian in the same district.

Fossil-collecting was carried out in Shropshire in 1892–1893 by Mr. J. Rhodes and in 1914 by Mr. W. Manson, both working under the direction of the late Charles Lapworth. The collections then obtained, so far as they pertain to districts now being mapped, have been examined by Dr. Stubblefield during the past year. He has recognized specimens of *Nemagraptus gracilis* (Hall) among the material collected by Mr. Manson from the Hoar Edge Grit. These and associated graptolites have been submitted to Miss G. L. Elles, who has confirmed the identification of *N. gracilis* and has recognized further members of the zonal assemblage bearing that name. Dr. Stubblefield has also visited the quarry at the east end of Black Dick's Coppice, 300 yards south of Evenwood and 1¼ miles E.S.E. of Acton Burnell; he has located the main shale-band in which these graptolites were first found, and has identified further species of graptolites indicating this zone. The band occurs near the top of the horizon of *Orthis* (*Harknessella*) *subplicata* recently described by Mr. B. B. Bancroft.[1]

[1] 'The Harknessellinae,' *Mem. and Proc. Manch. Lit. and Phil. Soc.*, vol. lxxii, 1928, p. 183.

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The finding of this graptolite-zone in the basal member of the Caradocian succession in the 'type outcrop' of the Caradoc district enables correlation to be made between this horizon and part of the Upper Glenkiln series of Scotland. It also gives support to the decision adopted by the Geological Survey in 1909 to draw the boundary-line between the Caradocian and the Llandilian in South Wales at the base of the Zone of *Nemagraptus gracilis*.[1] With the assistance of Mr. W. Dewar, Dr. Stubblefield also collected evidence of the occurrence of the upper part of this zone in the shale-development seen to the north-east of the Breidden Hills; there, the *N. gracilis* Zone is succeeded by shales and ashes yielding the fauna of the *Mesograptus multidens* Zone.

Among the material collected by Mr. Dewar from the Lower Caradoc beds of Montgomeryshire, Dr. Stubblefield has recognized a specimen of particular interest, the earliest Eurypterid arthropod so far recorded in this country. This, he considers, shows some affinity with *Drepanopterus*, a subgenus of *Stylonurus*. Its associates are entirely graptolites (Zone of *Mesograptus multidens*).

The examination of specimens obtained from the marine beds in the Middle Coal Measures in shaft-sinkings at Cefn Coed, near Neath, has shown the presence of interesting new fossils. Some teeth of the genus *Edestus*, so rare in this country, have been studied by Professor D. M. S. Watson, and have been found to belong to a new species. A description of them has been prepared (see the second part of the present *Summary of Progress*). Specimens of corals, providing a novel element in these particular associations, are being investigated by Dr. Stanley Smith, while Mr. W. S. Bisat is examining the cephalopods, which he finds to be representative of new species. Reports on these fossils will appear in due course.

In connexion with the preparation of specimens from the area of the Reigate Sheet, for the purpose of the forthcoming memoir, Mr. A. G. Davis has named a large amount of microscopic material from the Lower Greensand and from Chalk flint-meal. He has identified specimens of sponges, Foraminifera, ostracods, and Polyzoa, and has made a fine series of slide-preparations.

A considerable amount of work has been done in naming and registering some of the older collections, in preparation for the impending removal to a new building. Among other sets of specimens thus dealt with, collections from the Chalk of Trimingham and from the Lower Tertiaries of the Hampshire Basin, referred to in literature, have now been rendered more readily available for reference and study.

The following specimens in the Museum have been figured, described or mentioned in publications:—

[1] Cantrill, T. C., and H. H. Thomas in 'The Geology of the South Wales Coalfield, Part x. The Country around Carmarthen' (*Mem. Geol. Surv.*), 1909, p. 46.

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IN THE PALAEONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1927 (Published 1929).

A Monograph of the Terebratulidae of the British Chalk.

By DR. M. R. SAHNI, M.A., D.I.C., F.G.S.

Gibbithyris gibba *Sahni*, pl. ii, figs. 33-35 ; pl. viii, fig. 30, p. 20.
,, turonica *Sahni*, pl. iii, figs. 28-30 ; pl. ix, fig. 2, p. 29.
,, seafordensis *Sahni*, pl. iv, figs. 17-19, p. 26.
Carneithyris ornata *Sahni*, pl. iv, fig. 28 ; pl. x, fig. 22, p. 35.
,, norvicensis *Sahni*, pl. iv, fig. 29, p. 34.
,, uniplicata *Sahni*, pl. iv, fig. 30 ; pl. x, fig. 18, p. 35.
,, gracilis (*Sahni*), pl. v, figs. 26-28 ; pl. ix, figs. 11, 13, p. 36 (2 specimens).
,, subpentagonalis *Sahni*, pl. ix, fig. 7, p. 31.
Magnithyris magna *Sahni*, pl. v, figs. 1-3 ; pl. x, fig. 7, p. 39.
Chatwinothyris subcardinalis *Sahni*, pl. v, figs. 20-22 ; pl. x, fig. 4, p. 40.
Chatwinothyris ? symphytica *Sahni*, pl. x, fig. 13, p. 42.
Neoliothyrina obesa *Sahni*, pl. ix, figs. 19, 21, p. 9.

A Monograph of British Corallian Lamellibranchia.

By DR. W. J. ARKELL, M.A., B.SC., F.G.S.

Navicula (Eonavicula) quadrisulcata (*J. de C. Sowerby*), pl. i, fig. 3, p. 36.
Barbatia pectinata (*Phillips*), pl. i, fig. 12, p. 41.
Isoarca texata *Quenstedt*, pl. i, fig. 16, p. 47.
,, multistriata *Etallon*, pl. i, figs. 17, 17a (2 views), p. 47.
Placunopsis radiata (*Phillips*), pl. iii, figs. 4, 5, p. 49 (3 specimens).
Trigonia perlata *Agassiz*, pl. iv, fig. 2, p. 67.
,, spinifera *d'Orbigny*, pl. iv, figs. 8, 9.
Mytilus ungulatus *Young and Bird*, p. 52.

IN THE QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY, VOLUME LXXXV.

Drifted Plant-Beds of the Upper Estuarine Series of Yorkshire.

By MR. M. BLACK, B.A., F.G.S.

Ginkgoites Huttoni (*Sternberg*), p. 433.

IN THE ANNALS AND MAGAZINE OF NATURAL HISTORY, VOLUME III, TENTH SERIES.

On the Silurian Corals, Madreporites articulatus, *Wahlenberg, and* Madrepora truncata, *Linnaeus.*

By DR. STANLEY SMITH, M.A., F.G.S., and MR. R. TREMBERTH, B.SC.

Xylodes articulatus (*Wahlenberg*), pl. vii, fig. 4, p. 364, and text-fig. 2E, p. 371 (2 specimens).

On the Avonian Coral Caninophyllum, *gen. nov., and* C. archiaci (*Edwards and Haime*).

By MR. H. P. LEWIS, M.A., F.G.S.

Caninophyllum archiaci (*Edwards and Haime*), pl. xi, figs. 1a—c, and text-figs. 1a, a^1, p. 459.

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Notes on the Mesozoic Family Tancrediidae, *with Descriptions of several British Upper Jurassic Species, and of a new Genus,* Eodonax.

By Mr. L. R. Cox, M.A., F.G.S.

Tancredia astartiformis *Cox*, pl. xiii, figs. 1, 2, p. 575.
Corbicellopsis unioides (*de Loriol*), pl. xiii, figs. 3—5, p. 582.
,, swindonensis *Cox*, pl. xiii, figs. 6, 8, 9a, b, p. 580.
,, lorioli *Cox*, pl. xiii, fig. 7, p. 581.
Eodonax dukei (*Morris and Lycett*), pl. xiv, figs. 3, 4, p. 585.
,, pellati (*de Loriol*), pl. xiv, figs. 10, 11, p. 588.
Eodonax (?) eastonensis *Cox*, p. 591.

In the Annals and Magazine of Natural History, Volume IV, Tenth Series.

Some new Carboniferous Lamellibranchs.

By Dr. A. E. Trueman, F.G.S.

Carbonicola recta *Trueman*, text-fig. 2, p. 86 (2 specimens).
,, pseudacuta *Trueman*, text-fig. 3, p. 87 (2 specimens).
,, ornata *Trueman*, text-fig. 4, p. 88.
,, decorata *Trueman*, text-fig. 5, p. 90 (2 specimens).
,, regularis *Trueman*, text-figs. 6, 7a, b, pp. 91, 92 (2 specimens).
Carbonicola *cf.* regularis *Trueman*, text-fig. 8, p. 92.
Anthracomya prisca *Trueman*, text-fig. 9, p. 93.
,, lenisulcata *Trueman*, text-fig. 10, p. 94 (2 specimens).

In the Proceedings of the Leeds Philosophical Society Volume I, Part ix.

On the Lower Carboniferous Corals—Orionastraea *and its Distribution in the North of England.*

By Mr. R. G. S. Hudson, M.Sc., F.G.S.

Orionastraea phillipsi (*M'Coy*), pl. iv, figs. 1a, b, p. 444.
,, edmondsi *var.* laciniosa *Hudson*, pl. iv, fig. 2, p. 447.
,, edmondsi *Hudson*, p. 447.
,, prerete *Hudson*, p. 448.
,, rete *Hudson*, p. 448.
,, garwoodi *Hudson*, p. 449.
,, ,, *var.* sera *Hudson*, p. 450.

In the Proceedings of the Dorset Natural History and Archaeological Society, Volume L.

A Synopsis of the Lamellibranchia and Gastropoda of the Portland Beds of England.
Part I.—*Lamellibranchia.*

By Mr. L. R. Cox, M.A., F.G.S.

Parallelodon dorsetensis *Cox*, pl. i, fig. 4, p. 142.
Parallelodon *cf.* nobilis (*Contejean*), pl. i, figs. 5a, b, p. 142 (2 specimens).
Pteria chilmarkensis *Cox*, pl. ii, fig. 1, p. 145.
Buchia mosquensis (*v. Buch*), pl. ii, fig. 2, p. 146.
Pseudomonotis portlandica *Cox*, pl. ii, fig. 5, p. 146.

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Ostrea chicksgrovensis *Cox*, pl. ii, fig. 7, p. 148.
Trigonia buckmani *Cox*, pl. ii, fig. 9, p. 155.
,, wightensis *Strand*, pl. iii, fig. 1, p. 160.
,, aylesburiensis *Cox*, pl. iii, fig. 4, p. 153.
,, gibbosa *J. Sowerby*, *var.* manseli *Lycett*, p. 159 (2 specimens).
,, ,, *var.* tenuitexta *Lycett*, p. 160.
Chlamys sp., pl. iii, fig. 3, p. 161.
Mytilus suprajurensis *Cox*, pl. iv, fig. 1, p. 168.
Plicatula lamellosa *Cox*, pl. iv, fig. 3, p. 164.
Pholadomya rustica *Phillips*, pl. v, fig. 1, p. 172.
Eodonax (?) eastonensis *Cox*, pl. v, fig. 2, p. 179.
Eodonax dukei (*Morris and Lycett*), pl. vi, fig. 7, p. 178.
Isocyprina elongata *Cox*, pl. v, fig. 4, p. 174.
Thracia incerta (*Thurmann*), pl. v, fig. 6, p. 173.
Anisocardia buckmani *Cox*, pl. v, fig. 7, p. 175.
Eocallista pulchella (*de Loriol*), pl. vi, fig. 1, p. 187.
,, courcellensis (*de Loriol*), pl. vi, fig. 3, p. 189.
Corbicellopsis lorioli *Cox*, pl. vi, fig. 2, p. 178.
,, swindonensis *Cox*, p. 177.
Quenstedtia portlandica *Cox*, pl. vi, fig. 5, p. 191.
Pseudisocardia (?) rotunda *Cox*, pl. vi, fig. 8, p. 183.
Pronoella nuculaeformis (*Roemer*), pl. vi, figs. 9a, b, p. 184.
Corbula chilmarkensis *Cox*, pl. vi, figs. 10a—c, 11a—c, p. 194.
Pinna constantini *de Loriol*, p. 143.

In the Scientific Proceedings of the Royal Dublin Society, Volume XIX (New Series).

On the Structure of Palaeacis.

By Dr. L. B. Smyth, M.A., M.R.I.A.

Palaeacis axinoides *Smyth*, pl. vii, fig. 6, p. 131 (5 specimens).

In Memoirs of the Geological Survey. Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for the Year 1928, Part ii.

IV.—*The Zonal Succession in the Coal Measures around Manchester.*

By Dr. W. B. Wright, M.I.M.E., F.G.S.

Anthracomya cymbula *Wright*, pl. i, fig. 1, p. 50.
,, oblonga *Wright*, pl. i, fig. 2, p. 48.
,, librata *Wright*, pl. i, fig. 3, p. 49 (4 specimens).
,, fisheri *Wright*, pl. i, figs. 4, 4a, b, p. 47 (2 specimens).
Carbonicola *aff.* boltoni *Wright*, pl. i, figs. 6, 7, p. 37 (2 specimens).
Carbonicola boltoni *Wright*, pl. i, figs. 5, 5a, b, p. 37 (3 specimens).
,, radiata *Wright*, pl. i, figs. 8, 8a, b, p. 46 (3 specimens).
,, carissima *Wright*, pl. i, figs. 9, 9a, p. 42 (14 specimens).
,, acutella *Wright*, pl. i, figs. 10, 10a, b, p. 45 (3 specimens).
,, concinna *Wright*, pl. i, figs. 11, 11a, b, p. 44.
,, retrotracta *Wright*, pl. ii, figs. 1, 1a, b, p. 43 (2 specimens).
,, elliptica *Wright*, pl. ii, figs, 2, 2a, b, 3, p. 40 (6 specimens).
,, os-lancis *Wright*, pl. ii, figs. 5, 5a, b, 6, p. 38 (3 specimens).
,, ,, *var.* pectorata *Wright*, pl. ii, fig. 7, p. 40.
,, cycloquadrata *Wright*, pl. ii, fig. 8, p. 41.

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VI.—*On the Fossil Xiphosura from the South Wales Coalfield with a note on the Myriapod* Euphoberia.

By Miss E. Dix, M.Sc., F.G.S., and Mr. J. Pringle, F.G.S.

Belinurus concinnus *Dix and Pringle*, text-fig. 1, p. 92.
,, *cf.* arcuatus *Baily*, text-fig. 7, p. 99.
Prestwichianella nitida *Dix and Pringle*, text-fig. 9, p. 102.
,, *aff.* rotundata (*Prestwich*), p. 103 (2 specimens).
Euproops graigolae *Dix and Pringle*, text-fig. 10, p. 104.
,, gwenti *Dix and Pringle*, text-fig. 11, p. 106 (2 specimens).
,, islwyni *Dix and Pringle*, text-fig. 12, p. 107 (2 specimens).
,, meeki *Dix and Pringle*, text-fig. 13, p. 108 (2 specimens).
,, *aff.* danae *Meek and Worthen*, p. 112.
,, sp., p. 112 (3 specimens).
Euphoberia sp. nov. ?, p. 113 (2 specimens).

VIII.—*The Occurrence of a Rhyolite between the Ordovician and Pre-Cambrian Rocks near Habberley, Shropshire.*

By Mr. T. H. Whitehead, M.Sc., A.R.C.Sc.

Climacograptus antiquus *Lapworth*, p. 121 (11 specimens).
,, bicornis (*Hall*), (6 specimens).
,, caudatus *Lapworth*, (2 specimens).
? ,, wilsoni *Lapworth*, (2 specimens).
Cryptograptus tricornis (*Carruthers*), (15 specimens).
Diplograptus (Mesograptus) foliaceus ? *Murchison*, (3 specimens).
,, ,, multidens *Elles and Wood*, (6 specimens).
,, (Orthograptus) truncatus *Lapworth*, (2 specimens).
,, ,, ,, *var.* intermedius *Elles and Wood*
Orthis (Dalmanella) *cf.* testudinaria *Dalman*, (2 specimens).
Trinucleus concentricus (*Eaton*), (9 specimens).

In Memoirs of the Geological Survey England and Wales.

The Country around Moreton in Marsh.

By Mr. L. Richardson, F.R.S.E.

Dactylioceras annulatum (*J. Sowerby*), p. 33.
,, *cf.* gracile (*Simpson*), p. 33.
,, sp., p. 30.
Dactylioceras ?sp. nov., p. 31.
? Dactylioceras sp. nov., p. 31.
Hildoceras *cf.* bifrons (*Bruguière*), p. 31.
,, *aff.* hildense (*Young and Bird*), p. 31.
Porpoceras sp., p. 31.
Megalosaurus sp., p. 88.
Steneosaurus sp., p. 89 (3 specimens).
Tancredia planata *Morris and Lycett*, p. 91.
Camptonectes lens (*J. Sowerby*), p. 92.
Lima cardiiformis *Morris and Lycett*, pp. 92, 119 (4 specimens).
,, semicircularis *Morris and Lycett* non *Goldfuss*, p. 116.
Mytilus sublaevis *J. de C. Sowerby*, p. 92.
Cyathopora pratti *Edwards and Haime*, p. 93.
Isastraea limitata (*Michelin*), p. 93 (2 specimens).
Microsolena excelsa *Edwards and Haime*, p. 93.
Pseudomelania communis (*Morris and Lycett*), p. 109.
Tulophorites *aff.* tulotus *S. Buckman*, p. 119.

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B. Scotland

Mr. D. Tait visited a number of sections in the Silurian rocks of the Hagshaw Hills and Lesmahagow inliers, and he successfully traced a fossiliferous horizon in Group 1 of Peach and Horne's classification from end to end of the Hagshaw Hills anticline. The same horizon has been recognized by him in the inlier of Lesmahagow. The specimens collected have not yet been examined in detail, but the presence of certain species shows clearly that the rocks referred by Peach and Horne to the Wenlock—Ludlow should now be placed in the Ludlow. This conclusion is in agreement with that arrived at on the completion of the recent re-mapping of the area by Mr. G. Ross.

Several specimens of outstanding interest have been added to the collections during the year. Amongst the material collected by Mr. Tait from rocks occupying a high position in the Lower Carboniferous of Northumberland, Mr. Pringle has noted the occurrence of species of *Conularia* and *Cyrtoceras* which prove to be new. A specimen of *Conularia* is probably the largest example of this shell hitherto found in Britain. A description of these fossils will be given at an early date, in view of their interest. From the same district Mr. Tait obtained several specimens of the rare lycopod *Sigillaria taylori*, which were identified by Dr. Crookall.

From Skipsey's Marine Band, which was passed through in shaft-sinkings at Overtown, near Wishaw, Mr. W. Manson obtained two spines of the rare fish *Listracanthus wardi*. The spines of this vertebrate, which are restricted to the horizons of the Mansfield Marine Band and the higher Top Marine Band in England, have not previously been found in the Scottish Coal Measures, but their discovery in Skipsey's Band in association with other fossils characteristic of the Mansfield Marine Band may be regarded as affording conclusive proof of the equivalence of these marine deposits. This correlation with the Mansfield horizon has frequently been put forward by Mr. Pringle, who based his opinion on the identity of the molluscan fauna of these bands in Scotland and England, so that the evidence provided by the occurrence of *L. wardi* gives satisfactory confirmation.

A small collection of fossils presented by Mr. H. M. Cadell of Grange, Linlithgow, contains some excellent examples of *Protoschizodus axiniformis* (Portl.), *Sanguinolites variabilis* (M'Coy) and *Streblopteria ornata* (R. Eth., jun.). These shells were obtained from the blaes between the Main and Smithy Coal at Bridgness Colliery. In Scotland, *Streblopteria ornata* is a useful shell for the purpose of correlation. It has a fairly narrow vertical range, and is only found between the Hurlet Limestone and the shales above the Smithy Coal in the lower part of the Limestone Coal Group. It is possible that its value as an index-fossil may be more than local, and in this connexion it is significant that it has been recorded from only one

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horizon in the Brampton district in Cumberland, where it occurs above the Firestone Band throughout the area.

The Old Red Sandstone of Orkney and Shetland has yielded a further interesting suite of fossil fishes, which have been under examination by Professor D. M. S. Watson, F.R.S. A few fossil plants have also been obtained during the mapping of these islands, and, as on former occasions, the specimens have been submitted to Professor W. H. Lang, F.R.S., for study.

F. L. KITCHIN.

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2.—PALAEOBOTANICAL WORK

Identifications of fossil plants have been made during 1929 by Dr. Crookall from one-inch Sheets 85, 88, 152, 153 and 231 (England) and from one-inch Sheets 9, 14, 22, 23, 31, 39 and 40 (Scotland), as well as from a large number of boreholes. Numerous miscellaneous enquiries have been answered, and assistance has been given to research workers and others. In particular, help was given to Mr. W. Hemingway, who is describing new species of *Sphenophyllum*, and to Mr. P. E. Hall in an attempt to elucidate the apparently anomalous chemical behaviour of certain coals. Professional assistance was received from Miss E. Bolton, M.Sc., of Bristol Museum, who is collaborating with the palaeobotanist in an investigation of the affinities of the Pecopterids.

Fossil woods have been sectioned and investigated from various horizons, including Coal Measures, Oolite, Lower Greensand and the Chalk. Although a piece of wood has been recorded from the Chalk previously, it was not sectioned. The remains here referred to came from the Coranguinum Zone at Effingham and proved to represent secondary xylem of the Abietineous type. They will receive detailed description in the memoir which is in preparation. Fragments of badly preserved wood of a lignitic nature have also been sent in by Mr. R. D. Wilkie of Glasgow. They are of early Tertiary age and were collected from the Isle of Canna, Inverness-shire.

A considerable amount of time has been given to identifying the fossil plants collected from the Merthyr area, and in preparing the palaeobotanical section for the forthcoming memoir on one-inch Sheet 231. Our knowledge of the palaeobotany of this district has been small, but, with the assistance of Mr. W. D. Ware of Ystradgynlais, Swansea, extensive collecting has been carried out and some thousands of records have been obtained. The palaeobotanist also visited the Edinburgh office and there identified a number of fossils for the Sheets under revision. The plant sections and lists in the various Survey publications have been revised and checked.

In the Museum the exhibit of fossil plants from the Kidston Collection has been rearranged to illustrate the stratigraphical distribution of Coal Measure plants, and a temporary exhibit has been made to show specimens recently described and figured.

A number of fossil plants from the Kidston Collection were figured during the year in R. Crookall's 'Coal Measure Plants': these will be indicated in the Catalogue of the Kidston Collection now ready for press.

The preparation of the Second Section of Kidston's 'Fossil Plants of the Carboniferous Rocks of Great Britain' has been commenced. The next part will include *Desmopteris*, *Alethopteris* and part of *Neuropteris*.

R. CROOKALL.

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3.—PETROGRAPHICAL WORK

The work of the Petrographical Department, apart from routine duties, and as far as the Petrographer is concerned, has been mainly in connexion with the completion of the memoir of the important Tertiary district of Ardnamurchan. The districts at present undergoing re-survey have involved the description of Old Red Sandstone igneous rocks from the Cheviot Hills, and from the Longmyndian and other ancient rocks of Shropshire (Wrekin and Pontesford). The results of such work will be found in the reports of the various field units concerned. The Department has received valuable assistance from members of the field staff who have made themselves responsible for the current petrographical work connected with various regions. Mr. A. G. MacGregor has undertaken the descriptive petrography of the Ayrshire lavas and intrusions, Dr. Read that of the regions at present being surveyed in Sutherlandshire, and Mr. Bailey the Lewisian of the Island of Coll. The Director is dealing with the igneous rocks of the Orkney Islands, as the subject is one with which he is specially familiar.

The Petrographer noted an interesting suite of basic vesicular lavas at Memberly at the north end of the Cross Fell Inlier, and Dr. Bernard Smith undertook a brief field-examination of the exposures. These lavas, regarded by previous writers as of Ordovician (Borrowdale) age, are in part olivine basalts with a decidedly Carboniferous aspect. The age of the rocks, however, has not yet been determined, but if they belong to the Ordovician they stand alone amongst the Lake District lavas in containing olivine. Professor Watts detected and commented on the presence of olivine in a lava collected from Memberly in 1894 but his finding, preserved in the Survey records, was never published.

In addition to the identification of many rocks and specimens of archaeological interest the Petrographer has been, and is, engaged in reviewing the neolithic implements in the Manx Museum, collected from the Isle of Man. It is interesting to note the occurrence of kentallanite, of presumably Scottish derivation, among the rocks fashioned into implements. He has also reviewed the Roman sculptures in the London Museum and found in London, which are mainly of Inferior Oolite from the West of England.

HERBERT H. THOMAS.

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4.—CHEMICAL WORK

The quantitative analyses completed during 1929 included seven igneous rocks for various regional memoirs, four rocks from Persia, and partial or special analyses of two Shropshire and two Ayrshire rocks.

836. *Olivine-rich Sub-ophitic Dolerite.* (Olivine partly serpentinised; much interstitial viriditic material with a very small amount of analcite). Gallaston Quarry, 1½ miles W. of Kirkcaldy, on south side of the Kirkcaldy-Auchtertool road, and ½ mile N.W. of Balwearie Castle. 6-inch map, Fife, 35 S.E. Slice No. S. 25078. [*Note*: The specimen is from the type locality of the 'Gallaston type' of olivine-dolerite (Hatch and Watts). The rock is no longer used as a 'type' by Survey workers [1].

892. *Cummingtonite-cordierite-hornfels.* Near granite, occurring along coast between North Zawn and Wheal Edward Zawn, Carn Kenidjack. 6-inch map, Cornwall, 67 S.W. Slice No. E. 14585.

885. *Markle Basalt.* (Kilsyth variety). Lava. Yelping Craigs, 900 yds. E. by S. of Greenshieldhouse, 2½ miles N.N.E. of Carnwath. 6-inch map, Lanark, 20 S.E. Slice No. S. 26398.

886. *Jedburgh Basalt.* Lava of Calciferous Sandstone age. 760 yds. 8°W. of S. of Calla Farm, 2½ miles N.N.E. of Carnwath. 6-inch map, Lanark, 26 N.E. Slice No. S. 26395.

887. *Non-porphyritic Basalt.* Plug, probably of Calciferous Sandstone age. Kersewell Quarry (road-metal), 2 miles E.N.E. of Carnwath. 6-inch map, Lanark, 26 N.E. Slice No. S. 26401.

Lab. Nos.	836	892	885	886	887	888	889
SiO_2	44.95	48.87	46.54	46.89	43.73	45.84	45.94
Al_2O_3	13.53	16.71	17.41	13.74	13.73	15.79	15.64
Fe_2O_3	1.56	0.13	3.55	3.88	2.74	4.06	3.29
FeO	9.60	12.85	7.49	10.56	8.87	8.33	9.18
MgO	12.67	9.60	4.35	4.72	8.33	6.63	6.53
CaO	8.75	5.42	9.98	8.01	10.76	9.05	9.27
Na_2O	2.07	1.61	3.06	3.18	3.06	2.82	2.97
K_2O	0.79	0.27	1.04	1.46	1.35	1.03	1.23
$H_2O>$ 105° C. ...	3.11	0.99	2.01	1.85	3.48	2.23	1.87
$H_2O<$ 105° C. ...	0.54	0.07	1.14	0.96	0.48	0.52	0.50
TiO_2	1.86	2.71	3.29	4.04	3.22	3.17	3.03
P_2O_5	0.22	0.50	0.28	0.45	0.37	0.27	0.27
MnO	—	—	0.17	0.16	0.16	0.15	0.16
CO_2	0.04	0.07	0.00?	0.35	0.00?	0.02	0.14
FeS_2	0.07	--	0.05	0.09	0.09	0.05	0.02
Fe_7S_8	—	—	0.00	0.00?	0.00	0.00	0.00
Cr_2O_3	0.04	0.01	0.00	0.00?	0.02	0.00?	0.00?
NiO, CoO	0.04	--	—	—	--	—	--
BaO	—	--	0.03	0.05	0.01	0.05	0.01
Li_2O	0.00	—	0.00	0.00	0.00	0.00?	0.00?
Totals ...	99.84	99.81	100.39	100.39	100.40	100.01	100.05
Analysed by					B. E. Dixon.		

1 MacGregor, A. G., *Trans. Geol. Soc. Glasgow*, vol. xviii, part 2, 1928, p. 339.

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888. *Micro-porphyritic Basalt* with glassy base. ? Lava; small isolated area of basalt in Upper Old Red Sandstone area. Quarry, Arthurshields, Libberton Parish, about 1½ miles 30°E. of N. of Quothquan Church. 6-inch map, Lanark, 33 N.E. Slice No. S. 26399.

889. *Non-porphyritic Basalt.* (*Cf.* Jedburgh Basalt). ? Plug. Quarry, 40 yds. S.W. of Harecairns, Walston Parish. 6-inch map, Lanark, 27 S.W. Slice No. S. 26400.

890. *Bole* overlying basalt. 400 yds. N.E. of the Church, Little Wenlock. 6-inch map, Salop, 43 N.W. (W.).

891. ? *Bauxitic Clay* overlying basalt. Doseley Quarry. 6-inch map, Salop, 43 N.W. (E.).

Lab. Nos.	890	891
SiO_2	34.18	42.53
Al_2O_3	28.59	34.47
Fe_2O_3	19.18	1.65
FeO	0.74	0.26
MgO	0.37	0.45
CaO	0.34	1.11
TiO_2	4.50	5.14
Loss on ignition ...	12.20	14.09
Totals	100.10	99.70
Analysed by	B. E. Dixon.	

874. *Chamosite Mudstone* (? bauxitic). Bank of small stream, 300 yds. W.24°N. of Gateside Farm, 2 miles E. of Ayr. 6-inch map, Ayr, 33 N.E.

875. *Chamosite Mudstone.* Bank of small stream, 300 yds. W.24°N. of Gateside Farm, 2 miles E. of Ayr. 6-inch map, Ayr, 33 N.E. Slice No. S. 22086.

Lab. Nos.	874	875
Insoluble residue ...	10.94	56.43
Soluble portion		
SiO_2	19.56	6.26
Al_2O_3	25.56	5.06
Fe_2O_3	—	2.03
FeO	31.86	15.79
MnO	0.03	0.04
CaO	0.22	0.18
MgO	1.54	0.95
P_2O_5	—	0.04
SO_3	0.11	0.09
CO_2	0.21	3.86

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Calculated mineral composition of soluble portion.		
$Ca_3(PO_4)_2$	—	0.09
$CaSO_4$	0.18	0.15
$CaCO_3$	0.26	0.13
$MnCO_3$	0.05	0.06
$MgCO_3$...	0.15	2.00
$FeCO_3$	—	7.20
Remaining oxides ...	78.45	24.67
Proportionate molecular composition of 'remaining oxides' (mainly chamosite).		
SiO_2	200	200
Al_2O_3	154	95 } 119
Fe_2O_3	—	24 }
(Fe,Mg)O	296	303
Analysed by	B. E. Dixon.	

Lab. Nos. 874 and 875 were analysed to determine their chlorite content by extraction with dilute hydrochloric acid.[1] When the percentage of chlorite is very high, as in the case of Lab. No. 874 (75% chamosite), only a portion of the chlorite can be dissolved within the time limits of the described method. The method was therefore slightly modified in order to admit of the complete extraction of the chlorite, after evidence had been obtained that fresh errors had not thereby been introduced into the method. The high proportionate molecular composition for Al_2O_3 (theoretically 100 for pure chamosite) is probably due to a soluble form of alumina in the mudstone; this assumption was supported by the results of solubility tests with alumina minerals.

B. E. Dixon.

1 'Special Reports on the Mineral Resources of Great Britain, vol. xxix, Iron Ores: Bedded Ores of England and Wales. Petrography and Chemistry.' (*Mem. Geol. Surv.*), 1925, p. 115.

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IV. MUSEUM OF PRACTICAL GEOLOGY

THE total attendance of visitors for the year was 20,814; of these 1,583 were Sunday visitors. Thirty-one demonstrations to parties from schools, scientific and technical institutions were given in the museum, the total attendance at these being 646.

Museum work has been necessarily confined to cleaning, registration and rearrangement of existing exhibits. The Cement exhibit was entirely rearranged and new material has been incorporated and labelled. A special case illustrating the structure and geology of coal has been arranged with the help of Dr. Crookall and a supplementary exhibit of micro-sections is in course of preparation. An exhibit of maps, memoirs and specimens was arranged for the Geologists' Association Annual conversazione at which demonstrations were given upon the microstructure of ornamental stones.

Cataloguing and registration of material have been carried on steadily. The card catalogue of Scottish geological photographs is now complete, upwards of 3,000 cards having been added during the year. Seven hundred specimens of the Lindsey Collection have been registered and card-indexed.

With the publication of the catalogue of selected photographs there has been an increasing public demand for prints and lantern-slides of Survey photographs, the number supplied by the museum staff being 576.

Geophysical work has again taken up a considerable portion of the time of the museum staff. During the year the gravitational results obtained over the Pentland Fault at Portobello were published and a certain amount of field work with the torsion balance was carried out over the magnetic anomaly mapped by Mr. Hallimond at Thrussington, Leicestershire. Reports on the results obtained by the Survey with the torsion balance were presented to the Institution of Mining and Metallurgy[1] and to the International Drilling Congress,[2] and have been published.

The Assistant Curator carried out magnetic surveys at Yarnfield, Staffordshire, and at Melton Mowbray, Leicestershire. The results of the first survey have been published whilst an account of the second is in preparation. Throughout this magnetic work valuable assistance has been given by the officers of the observatories at Kew and Abinger, especially by Mr. W. Stevens, who kindly transmitted the daily readings at Abinger to the field staff.

The additions to the Library during the past year comprise 297 volumes of independent works, 3,012 volumes and parts of serials, 150 pamphlets, 513 maps and 802 geological photographs. There has been a large increase in the number of prints and lantern slides supplied to the public, the total for the year being 1,610. An increasing number of students and professional enquirers continue to use the Library for study and research. W. F. P. McLintock.

[1] McLintock, W. F. P., and J. Phemister, 'The Use of the Torsion Balance in the Investigation of Geological Structure,' *Bull. Inst. Min. and Metall.*, No. 295, 1929, pp. 18-22.

[2] McLintock, W. F. P., and J. Phemister, 'Communication sur les Etudes Géophysiques en Grande-Bretagne,' IIe *Congrès International de Forage, Paris*, Sept., 1929.

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I.—ON THE MAGNETIC DISTURBANCES IN NORTH LEICESTERSHIRE

BY

A. F. HALLIMOND, M.A.

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Abnormally high values for both the vertical and horizontal components of the earth's magnetic field were observed by Rücker and Thorpe[1] near Melton Mowbray in their general magnetic survey of the British Isles. This result was confirmed by G. W. Walker in a re-survey in 1915.[2] The question whether these disturbances were due to any mineral formation of geological or commercial importance was referred by the Iron Ore Committee of the Conjoint Board of Scientific Societies to the Director of H.M. Geological Survey, who entrusted the geological part of the work to Dr. A. H. Cox, temporarily appointed to the Survey staff for this purpose. Observations of the components of the earth's magnetic field were made by Mr. Walker at three stations within the present area, and laboratory determinations of the magnetic susceptibility of the rocks were contributed by Professor E. Wilson. In their Report[3] published in 1919, these authors concluded that the disturbances were of local origin, and might be due to dykes or other masses of magnetic rock of which it was not possible to indicate precisely the extent or nature, since the structures were concealed beneath the non-magnetic surface rocks; the effects were not due to the exposed iron-bearing rocks of the Lias on the east or of Charnwood on the west. No further work on this subject appears to have been published, with the exception of re-determinations made at the Melton Mowbray station by H.M. Ordnance Survey in 1927.[4] I am indebted to Mr. H. L. P. Jolly of H.M. Ordnance Survey, who is engaged in the general magnetic survey of the British Isles, for a comparison (see p. 11) between the five existing determinations, including two additional to those above mentioned, and the present field-balance results for the same stations.

Stations in the General Magnetic Survey were selected without special reference to the geological structure, and were spaced at intervals of 10 miles or more apart. In concluding his report, Mr. Walker made the following observations (*op. cit.*, p. 71) which are of special interest in view of the recent development of the magnetic methods abroad :—

[1] *Phil. Trans. Roy. Soc.*, Ser. A, 1890, vol. 181, p. 288; 1896, vol. 188, pp. 602 and 626.

[2] *Phil. Trans. Roy. Soc.*, Ser. A, 1919, vol. 219, pp. 1-72. This will be referred to as 'Walker, *op. cit.*'

[3] *Phil. Trans. Roy. Soc.*, Ser. A, 1919, vol. 219, pp. 73-135. This will be referred to as 'Cox, *op. cit.*'

[4] 'Results of the Magnetic Observations made by the Ordnance Survey in England in 1927,' p. 5.

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"Magnetic surveying by the use of absolute instruments appears to me to be unnecessarily cumbrous and not conducive to the best results. Further, no standard of magnetic force exists at present by which instruments can be compared with an accuracy of 1 γ. It thus seems desirable that a standard should be prepared in terms of the electrical standards of the country. . . . The success attained [by the portable magnetometer] justifies a serious attempt to improve the instrument. . . .[1] Even if the instruments required comparison with a standard from time to time, their introduction would much reduce the field work of the Survey and would give greater accuracy. They would be specially useful in making detailed surveys of special regions and in proving if a station is really representative and not subject to disturbances of very local origin."

The Schmidt magnetic balance was designed in Germany in 1914[2] and standard forms of this instrument for determining the horizontal and vertical components have been placed upon the market by the Askania Company of Berlin. One vertical field-balance (No. 92986) and one horizontal field-balance (No. 93375) were acquired by H.M. Geological Survey in 1929. As a preliminary test, a magnetic survey[3] was made upon the southern end of the Swynnerton Dyke in Staffordshire, over which a torsion balance traverse had been made. It was next decided to make a more extended trial of the balances by investigating the magnetic anomaly near Melton Mowbray. Four visits were made to North Leicestershire, representing a total of 21 working days, and determinations of the vertical force were made at 372 stations. It soon became evident that the region was most suitable for vertical force survey, and attention was almost entirely confined to work with the vertical balance. A series of 10 test observations were, however, made with the horizontal balance, and these serve to show that this instrument is capable of giving satisfactory readings, while the values recorded are quite consistent with the interpretation given to the vertical force observations. The area covered by the present survey is shown in Figs. 2 and 3; it lies mainly to the south and west of Melton and measures roughly nine miles from east to west and eight from north to south, together with certain outlying features. It was chosen so as to include a large area of high vertical force which was discovered to be the main feature of the Melton anomaly; a contoured map of this area has been prepared (Fig. 2) and it will be shown that the results may be regarded as due to the existence of a 'floor' of older rocks, masked by the later formations, and containing in certain places well-defined areas of magnetic rock such as granite. Acknowledgment is due to the Astronomer Royal for the magnetic readings supplied by the Abinger Magnetic Station, to the Director General of H.M. Ordnance Survey

[1] An improved semi-portable instrument has recently been designed by Dr. F. E. Smith, 'A Portable Magnetometer of the Null type,' Ordnance Survey, 1930.

[2] Tät. Ber. des Kgl. Preuss. Meteor. Instituts, Berlin, 1914 and 1915.

[3] *Mining Magazine*, 1929, vol. xli, No. 1, pp. 16-22; reprinted in 'Summary of Progress' for 1929 (*Mem. Geol. Surv.*), 1930, pt. III, pp. 44-58.

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for permission to include a comparison with earlier determinations, and to the Air Ministry for facilities in working at Kew Observatory. Throughout this work I have been greatly indebted to Mr. W. Stevens of the Abinger Observatory for his very cordial assistance in ascertaining the corrections for diurnal variation, and to Mr. H. L. P. Jolly of H.M. Ordnance Survey in comparing the working of the various magnetometers.

Instrument

A brief description of the balance has already been given in the account of work on the Swynnerton Dyke. For the present purpose it was necessary to carry out the full correction for temperature, variation in the earth's field, and changes in the zero value of the instrument from day to day. Preliminary tests were made to ascertain the permissible latitude in levelling and orientation, and these will be described together with a few particulars in which special precautions were found desirable.

1. **Effect of errors in levelling the vertical balance.**—The balance is provided with two level-tubes placed at right angles. When readings are being taken one of these points E.-W., the other N.-S. Errors in the setting of the E.-W. level are eliminated (provided they are small) by rotation of the balance through 180° between the two sets of readings; but Heiland[1] has emphasized the importance of obtaining a true level in the N.-S. direction, since any error will cause the beam to swing in a plane inclined to the vertical, and this diminishes the apparent value for the vertical force in both E.-W. and W.-E. settings to an important extent. The two curves (*c*) and (*d*) in Fig. 1 show the relation between the displacement of the bubble in the level-tubes and the reading of the instruments. For the most accurate work the graduated levels were set so that they remained within about one scale division of the same reading when the instrument was rotated through four right angles after levelling the turn-table; an agreement of this order was verified at least on the N.-S. level before observations were made at each station.

The level-tubes are in open brass cases; they are liable to displacement if touched[2] and are also exposed to rain; celluloid covers were therefore fitted. Constant vigilance is necessary in levelling, as neglect in this respect is a fruitful source of error. As a precaution against disturbance the telescope and level-table were never touched except for the purpose of moving the jointed illuminating mirror and the operculum; this precaution is especially needed in packing the instrument, which is best handled by the wooden corner-pieces on the outer cover.

[1] 'Geophysical Prospecting,' *Amer. Inst. of Mining & Met. Eng.*, 1929, pp. 261-314. See especially p. 276.

[2] As a temporary measure in the field a little shellac varnish was poured into the cases to fix the tubes.

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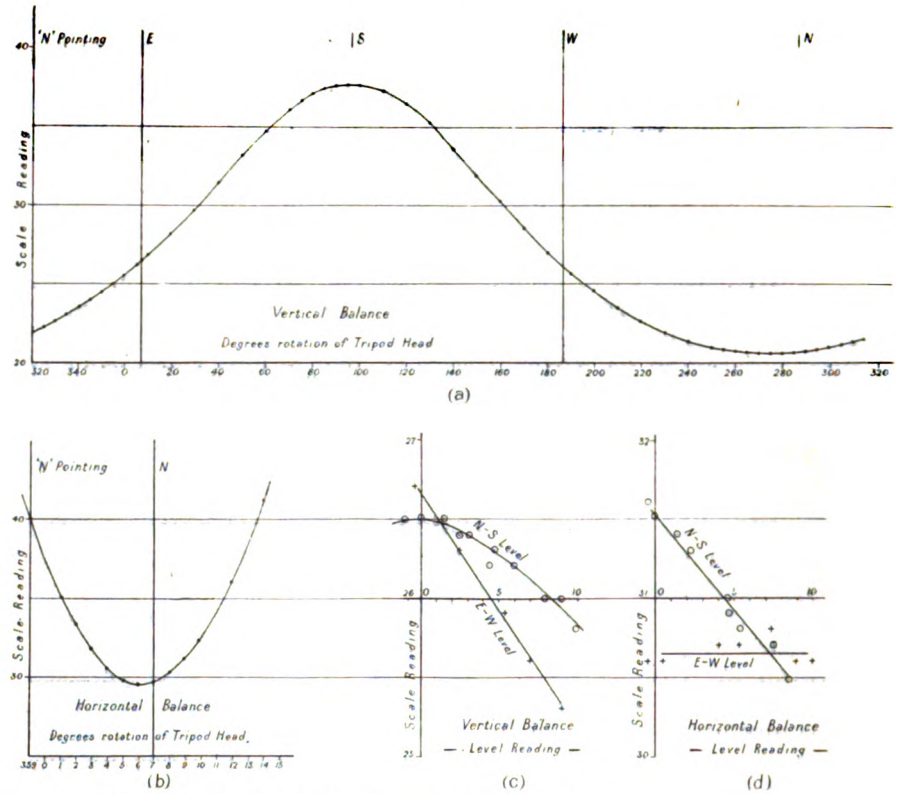

FIG. 1.—*Effect of errors in setting the magnetic balances.*

(*a*) *Vertical balance. Relation between scale-reading and deviation from correct E.-W. setting.*

(*b*) *Horizontal balance. Relation between scale-reading and deviation from correct N.-S. setting.*

(*c*) *Vertical balance. Relation between scale-reading and position of bubble in the levels.*

(*d*) *Horizontal balance. Relation between scale-reading and position of bubble in the levels.*

2. **The release.**—Whether owing to climatic conditions or to other causes, it was found that during the ' release ' movement the cradle did not readily detach itself from the beam after the knife-edge had begun to swing on the quartz-plate. As a result one end of the beam, in this case always the ' north ' end, was drawn down with the cradle, till the reading was displaced beyond the limits of the visible scale. Then the beam was suddenly freed and returned to its proper equilibrium position with a violent oscillation. Under these conditions the readings could not be repeated with accuracy, no doubt owing to small displacements of the position of the knife-edges. The trouble seemed to be especially marked on certain days, as though it were due to oil or moisture at the contact

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of beam and cradle. It was completely obviated by making the release in two stages, as follows :—(1) The release lever is slowly turned until the knife-edge makes contact with the quartz-plate ; at this point the image of the scale begins to swing steadily away from the centre, following the movement of the lever. When this movement has progressed to a suitable point, usually near the end of the visible scale, (2) the release is rather sharply lowered, care being taken not to cause any jar to the instrument. In this way a smart shock is given to the contact between beam and cradle and this appears to be sufficient to separate them, though the energy transmitted to the beam is not enough to cause any marked displacement, provided the shock is definite and is given quickly. The beam is thus freed at a point near the end of the scale and returns quietly to its position of equilibrium, at which the reading is taken. When this procedure had been adopted no further difficulty was experienced in the release, and repeated settings could be made with a difference rarely greater than 0·1 scale division.

3. **Effect of errors in compass-setting.**—Before placing the balance in position for reading, the rotating tripod-head is orientated by means of a compass. Errors in orientation result in the incorrect placing of the beam and knife-edges in relation to the magnetic meridian, and consequently affect the reading of both horizontal and vertical balances. The effect of error can be seen from the curves (*a*) and (*b*) in Fig. 1, which were obtained by taking readings at settings intentionally directed away from the true magnetic north, the amount of deviation in setting being read on the graduated tripod-head. In the case of (*a*) it should be noted that the effect of the earth's horizontal force, which operates when the beam is incorrectly placed, depends upon the relation of the beam and knife-edges to the horizontal plane ; so that the form of curve (*a*) depends upon the reading of the scale at the E.-W. setting. The error in setting should not exceed half a degree.

4. **Packing.**—During transport the vertical balance is retained in its mahogany case by two rather stiff springs that press upon the top of the balance. In returning it to the case after use it was found that considerable force was required to insert the balance beneath the springs, and there seemed reason to believe that the outer cover of the balance was being warped, with a consequent disturbance of the levels and variation in the zero-reading. In order to obviate this the two fixed brass stops at the outer ends of the springs were replaced by wooden blocks turning on pivots, so that the pressure of the springs could be released before the balance was removed from the case.

5. **Temperature gradients.**—Both the manufacturers and Heiland have drawn attention to the error caused by a temperature gradient within the instrument. The present observations were not

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suited for verification of this effect, but it should be noted that in other work it was found that errors of more than 10 γ could be caused by sudden exposure of the instrument to a change of a few degrees in temperature. In accurate work care should always be taken to allow time (at least 15 minutes) for recovery after a sudden change such as may arise on first opening the case after a change in the air temperature.

When due care is taken, the results at successive closely-placed stations along a traverse can be reproduced within about 0·1 scale division (3 γ); but in more extended traverses there is a tendency to develop small but appreciable errors which may be corrected if necessary by a repetition of the reading at the base and distribution of the error; if serious change has occurred the traverse must be repeated. The cause of these errors has not been fully ascertained; they have been attributed to changes in the centre of gravity of the beam.[1]

METHOD OF SURVEY

In the present survey, traverses of from four to eight miles were commonly made, and it was not possible to return to a base. The instrument was therefore assumed to remain in the same state during each traverse and a common traverse correction was applied to all the stations. This was determined on another day by linking together selected points from each of several traverses by means of a cross-traverse which included an observation either at the principal base or at a sub-base where the anomaly had already been ascertained. The traverse corrections were at first somewhat irregular, varying by about 60 γ, but when the above-mentioned difficulties in packing, etc., had been overcome, the last seven traverse corrections in the present survey showed an extreme variation of only 22 γ. It should be mentioned that these traverses were based upon sub-stations and extended more than ten miles from the principal base, while the instrument was brought back to London for an interval of one month in the middle of the series; also that the readings were corrected by means of the daily variations at Abinger and not by a special record at the principal base. In these circumstances the result may perhaps be regarded as typical of what is to be expected under ordinary field survey conditions. As to the cause of the small changes, it may perhaps be noted that the beam is magnetized by the earth's field when placed along the magnetic meridian. In future the instrument will be stored with the beam pointing E.-W. so as to avoid any tendency to impress slight changes of moment upon the beam during the intervals of disuse. The above traverse corrections clearly show that no serious error need result from rail transport; in the present case the traverses were generally completed on foot in the manner described

[1] Directions for the use of the Vertical Field Balance, p. 8.

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below ; the use of a motor car during one long traverse apparently gave rise to no serious error in the readings.

CORRECTION FOR VARIATION OF THE EARTH'S MAGNETIC FIELD

The observed magnetic force is usually regarded as the sum of the earth's field (due to ' distant ' magnetized bodies and, to a small extent, to electric currents) and a constant ' local anomaly ' due to the rock masses near the point of observation. The earth's field is regarded as constant at any moment over the area under survey, so that the difference between simultaneous observations taken at a base and at a given station represents the difference in magnetic anomaly.[1]

Strictly speaking, the value of the anomaly is not constant, but varies with the earth's field at the time of observation ; for example, a change in the vertical force alone will affect not only the vertical but also the horizontal anomaly in the neighbourhood of a magnetized rock. But under normal conditions the variations in the earth's field are of the order of 100 γ, *i.e.*, they do not exceed one per cent. of the field value. The corresponding changes in the anomaly are roughly proportional to the changes in field and can therefore be neglected. For practical purposes the anomaly can be regarded as constant and a map showing the differences from a base station can be used at any time to obtain the force at a given point if the value at the base is known.

Over wider areas the above simple assumption requires modification. In the first place, the general magnetic survey of the British Isles has shown that the average value of the earth's field varies in a linear manner across the country. Over a distance of, say, ten miles the change is slight but quite appreciable. Near Melton the gradients[2] are roughly :

Component.	Gradient.	Direction of increasing value.
Vertical force V	59 γ in ten miles	N.20°W.
Horizontal component H ...	55 γ ,,	S.13°E.
Westward component ...	22 γ ,,	W.12°S.

In a variometer survey these appear as part of the observed difference from the base station ; they ought to be deducted from the observed difference in considering the true form of a widespread ' local anomaly,' though they are practically negligible in the case of an area less than one mile across. The values given in the map with the present Report represent real differences from the base, and include the gradient of the earth's field. Thus between Grimston and Knossington the difference of about 150 γ includes approximately 60 γ due to the general gradient.

[1] Notation : In the present Report H, V, etc., indicate the absolute value of the earth's magnetic components ; h, v, etc., the ' anomaly ' referred to a local base.

[2] Taken from charts, Walker, *op. cit.*

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A second complication that arises in dealing with a wide area is due to the fact that variations in the earth's field are neither equal nor simultaneous except for stations very near together. In foreign countries it is usually necessary in any case to take simultaneous observations at a special base within the area under survey. In England, however, it is generally accepted that for places on the same longitude the variation can be taken as roughly equal to that at the nearest magnetic observatory. The question was tested by Walker (*op. cit.*, pp. 8, 9), who showed that simultaneous observations at Cambridge and Greenwich, places on very nearly the same meridian, differed by a nearly constant value which did not vary by more than 15 γ in H. In places of different longitude the disturbances depend in part on the difference of time, and the question becomes more complicated. Fortunately, in the present case Melton Mowbray is upon nearly the same meridian (average 50′ W.) as the magnetic observatory at Abinger, their relative situation being similar to that of Cambridge and Greenwich. For the present purpose, therefore, a special base station was not employed; each field observation being corrected by a comparison with the simultaneous value at Abinger. Every traverse was completed within the day; the times of observation were forwarded each evening to Abinger, and corresponding values of the magnetic component were returned and used to correct for the diurnal variation during the traverse. Experience in the present survey confirms the view that for general purposes this method is adequate, the small loss in accuracy being amply compensated by the increased number of readings made possible by omitting signalling to, or return to, a base station. No doubt a continuous recording base established locally would yield a further improvement, but the cost of this (about £500) as well as the additional maintenance do not seem to be warranted. Generally speaking, the geological inferences from a magnetic survey would seem to be limited, not by the accuracy of the observations, but by the difficulty of completely calculating the effect of a natural rock-mass on account of the infinite variety of minor irregularities both in shape and composition. As soon as an attempt is made to take into account anomalies of less than, say, 10 γ, it may be found that, except in cases of very simple geological structure, the effects are liable to be masked by boulders or sand-beds in the Drift as well as by irregularities in the form of the 'solid' structures beneath. Larger anomalies, up to, say, 300 γ, often exhibit characteristic forms and can be correlated with the effects calculated for a 'geological model' representing in diagrammatic manner the principal rock-masses.

METHOD OF OBSERVATION AND CALCULATION OF RESULTS

Although it is possible for one observer to carry out a magnetic survey alone, a great improvement in speed, and, probably, in the elimination of stray errors, can be obtained when a technical

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assistant is available. The following routine was observed: (1) The observer must of course carry no iron objects such as keys, watch, buckles; these were handed over to the assistant during observations. (2) The observer selects a station upon which he adjusts and levels the tripod while the assistant unpacks the instrument at not less than 25 ft. from the station. This distance is necessary in order to avoid interference from the auxiliary magnets and compass. (3) The assistant brings the compass to the observer and returns to a point near the case in order to avoid interference from the magnetic material he may be carrying. (4) The observer sets the tripod head by compass; the assistant then brings up the balance, places it on the tripod and takes away the compass. (5) The balance is levelled and readings (usually two sets of 3) are taken and read out to the assistant, who enters them in his record-book, with the time of observation and the temperature, after which the observer marks the station on the map or plan. (6) The apparatus is dismantled and packed.

It will be readily understood that, apart from the labour of carrying the instruments on a long journey, the time taken at each station in the absence of an assistant would be very much longer, while the attention of the observer would be occupied by unnecessary detail. In very close-set traverses there is, of course, no need to pack the instrument between readings provided an assistant is available to carry the rest of the apparatus.

The record-book has the following headings :—

Traverse and Station.	Readings.	Mean.	Time and Temperature.
Rearsby, 24.10.29			G.M.T.
A	136, 135, 136		11·1
	137, 137, 137	13·6	14°
B	174, 174, 174		11·19
	177, 178, 177	17·6	13½°
C	157, 156, 156		11·28
	158, 159, 159	15·8	13½°

The last column contains also any remarks as to use of auxiliary magnets, etc.

In calculating the results it is convenient to express the reading for each station as the difference in γ from an arbitrary base value (in this case scale reading 20·0), and then apply corrections to a standard temperature, standard value of the earth's field and 'traverse correction.' The corrections were tabulated as follows :—

Traverse and Station	Reading −20·0	=γ	Corr. to to 10°C.	Corr. to V = 42900 at Abinger	Traverse corr. (to Woodlands)	Total corr.	Corr. value
Rearsby, 24.10.29							
A	−6·4	−194	+7·2	−35	+83	+55	−139
B	−2·4	−73	+6·3	−36	+83	+53	−20
C	−4·2	−127	+6·3	−38	+83	+51	−76

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A second complication that arises in dealing with a wide area is due to the fact that variations in the earth's field are neither equal nor simultaneous except for stations very near together. In foreign countries it is usually necessary in any case to take simultaneous observations at a special base within the area under survey. In England, however, it is generally accepted that for places on the same longitude the variation can be taken as roughly equal to that at the nearest magnetic observatory. The question was tested by Walker (*op. cit.*, pp. 8, 9), who showed that simultaneous observations at Cambridge and Greenwich, places on very nearly the same meridian, differed by a nearly constant value which did not vary by more than 15 γ in H. In places of different longitude the disturbances depend in part on the difference of time, and the question becomes more complicated. Fortunately, in the present case Melton Mowbray is upon nearly the same meridian (average 50′ W.) as the magnetic observatory at Abinger, their relative situation being similar to that of Cambridge and Greenwich. For the present purpose, therefore, a special base station was not employed; each field observation being corrected by a comparison with the simultaneous value at Abinger. Every traverse was completed within the day; the times of observation were forwarded each evening to Abinger, and corresponding values of the magnetic component were returned and used to correct for the diurnal variation during the traverse. Experience in the present survey confirms the view that for general purposes this method is adequate, the small loss in accuracy being amply compensated by the increased number of readings made possible by omitting signalling to, or return to, a base station. No doubt a continuous recording base established locally would yield a further improvement, but the cost of this (about £500) as well as the additional maintenance do not seem to be warranted. Generally speaking, the geological inferences from a magnetic survey would seem to be limited, not by the accuracy of the observations, but by the difficulty of completely calculating the effect of a natural rock-mass on account of the infinite variety of minor irregularities both in shape and composition. As soon as an attempt is made to take into account anomalies of less than, say, 10 γ, it may be found that, except in cases of very simple geological structure, the effects are liable to be masked by boulders or sand-beds in the Drift as well as by irregularities in the form of the 'solid' structures beneath. Larger anomalies, up to, say, 300 γ, often exhibit characteristic forms and can be correlated with the effects calculated for a 'geological model' representing in diagrammatic manner the principal rock-masses.

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assistant is available. The following routine was observed: (1) The observer must of course carry no iron objects such as keys, watch, buckles; these were handed over to the assistant during observations. (2) The observer selects a station upon which he adjusts and levels the tripod while the assistant unpacks the instrument at not less than 25 ft. from the station. This distance is necessary in order to avoid interference from the auxiliary magnets and compass. (3) The assistant brings the compass to the observer and returns to a point near the case in order to avoid interference from the magnetic material he may be carrying. (4) The observer sets the tripod head by compass; the assistant then brings up the balance, places it on the tripod and takes away the compass. (5) The balance is levelled and readings (usually two sets of 3) are taken and read out to the assistant, who enters them in his record-book, with the time of observation and the temperature, after which the observer marks the station on the map or plan. (6) The apparatus is dismantled and packed.

It will be readily understood that, apart from the labour of carrying the instruments on a long journey, the time taken at each station in the absence of an assistant would be very much longer, while the attention of the observer would be occupied by unnecessary detail. In very close-set traverses there is, of course, no need to pack the instrument between readings provided an assistant is available to carry the rest of the apparatus.

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C	−4·2	−127	+6·3	−38	+83	+51	−76

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FIELD WORK

Woodlands trigonometrical station of the Ordnance Survey, situated near the Oakham road about one mile south-east of Melton Mowbray, had been used as a magnetic station by Rücker and by Walker and Jolly, and was known to be within the field of the Melton anomaly. It was therefore taken as principal base for the present survey, and all the values given represent differences between the magnetic force at the respective station and the simultaneous value at the Woodlands base. In making observations at this base a difficulty arose because the field had been divided by a wire fence passing rather near to the base. A sub-base was therefore chosen at a short distance away, and the small difference between this and the true base was determined by means of a ring of stations surrounding the latter. In surveying the present area a measured traverse was first made down the northern half of the Woodlands field. Along this the high vertical force persisted almost unchanged and the line was therefore continued south-south-east across the neighbouring fields till a slight diminution became apparent. Another traverse about ¼ mile to the north-west also yielded high values, and it became clear that the region of high vertical force would cover a wide area. Journeys were then made along the roads leading southwards from Melton, with observations at intervals of about two fields' width. The stations were recorded by entering their approximate position directly upon the plan of the field on the six-inch ordnance map. Each was located as far as possible about 100 ft. from the hedge, so as to avoid stray fields due to concealed iron fencing, etc., and the obvious precautions were taken in avoiding the neighbourhood of buildings, pipes and power lines. Similar traverses were extended in the directions where high values were probable and so the map of the vertical anomaly (Fig. 2) was built up. The gradients of magnetic force are not steep (200-500 γ per mile) and measured traverses were therefore not made except in the special survey of the steep anomaly near Thrussington on the west of the main anomaly (p. 16).

COMPARISON WITH EARLIER OBSERVATIONS

Readings at three stations in this area are available in previously published work, and I am indebted to the Director General of H.M. Ordnance Survey for permission to include two values recently determined by Mr. H. L. P. Jolly in the course of the general magnetic survey. In order to obtain a general check on the present work, as well as to fill in a number of outlying points, a special long traverse was made by motor car over a total distance of 42 miles, beginning at the Woodlands base and encircling the area of the main vertical anomaly. Observations of vertical and horizontal force[1] were made at a number of stations (16 vertical and 10

[1] The correction in h due to changes in V is small and was ignored in the present observations (*cf.* Heiland, *loc. cit.*).

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horizontal), including the five stations Melton (Woodlands), Burrough Hill, Billesdon, Seagrave and Asfordby at which earlier results were available. The results were communicated to Mr. Jolly, who has very kindly supplied the following comparison.

"As regards vertical force, although H may be determined (as in 1929) within about 3 γ, yet the Dip Circle introduces an error which undoubtedly exceeds 1′ on occasion and may even reach 2′. This causes a difference of 50-70 γ in V, and the fact that none of the four comparisons tabulated below shows a discrepancy of more than 45 γ must be regarded as satisfactory. The values in the table below represent the difference between Walker's or my values and the value at Melton. As regards H, Walker gives the disturbing forces in the other rectangular components N and W. If δ N, δ W, δ H refer to departures at any station from the mean values of those quantities for the whole district we may, to a first approximation, write

$$\delta H = \delta N_{\cos} D_o + \delta W_{\sin} D_o$$

where D_o is a mean value of the declination through the area.

Taking $D_o = 15° 30'$ for 1917, Walker's values become—

δ H at Melton + 90 ; Seagrave + 21 ; Asfordby − 91.

"These yield the differences from Melton shown in the table below.

Station	δ H			δ V		
	Walker	Jolly	Halli-mond	Walker	Jolly	Halli-mond
Melton	0	0	0	0	0	0
Asfordby	−181		−189	−112		−92
Seagrave	−69		−92	−162		−132
Burrough Hill ...		+1	−2		−155	−110
Billesdon		−9	0		−48	−91

"Taking the accuracy of the Schmidt balance in H in a traverse of this kind as about 10 γ these results may be regarded as satisfactory throughout, with the possible exception of δ H at Seagrave."

H. L. P. J.

The remaining values for h in this traverse were as follows :— Whissendine (Oakham Road) −28 ; Keyham −50 ; Six Hills −27 ; Six Hills −60 ; Shoby −166.

On the north side, Six Hills (−60), Shoby (−166) and Asfordby (−189) clearly show an increasing southward force due to the large magnetic mass to the south of the last station. This inward pull is well seen if the values are increased to correspond with Walker's estimate +90 for the local anomaly in H at Melton (difference from the mean value for District V in the general survey). They then

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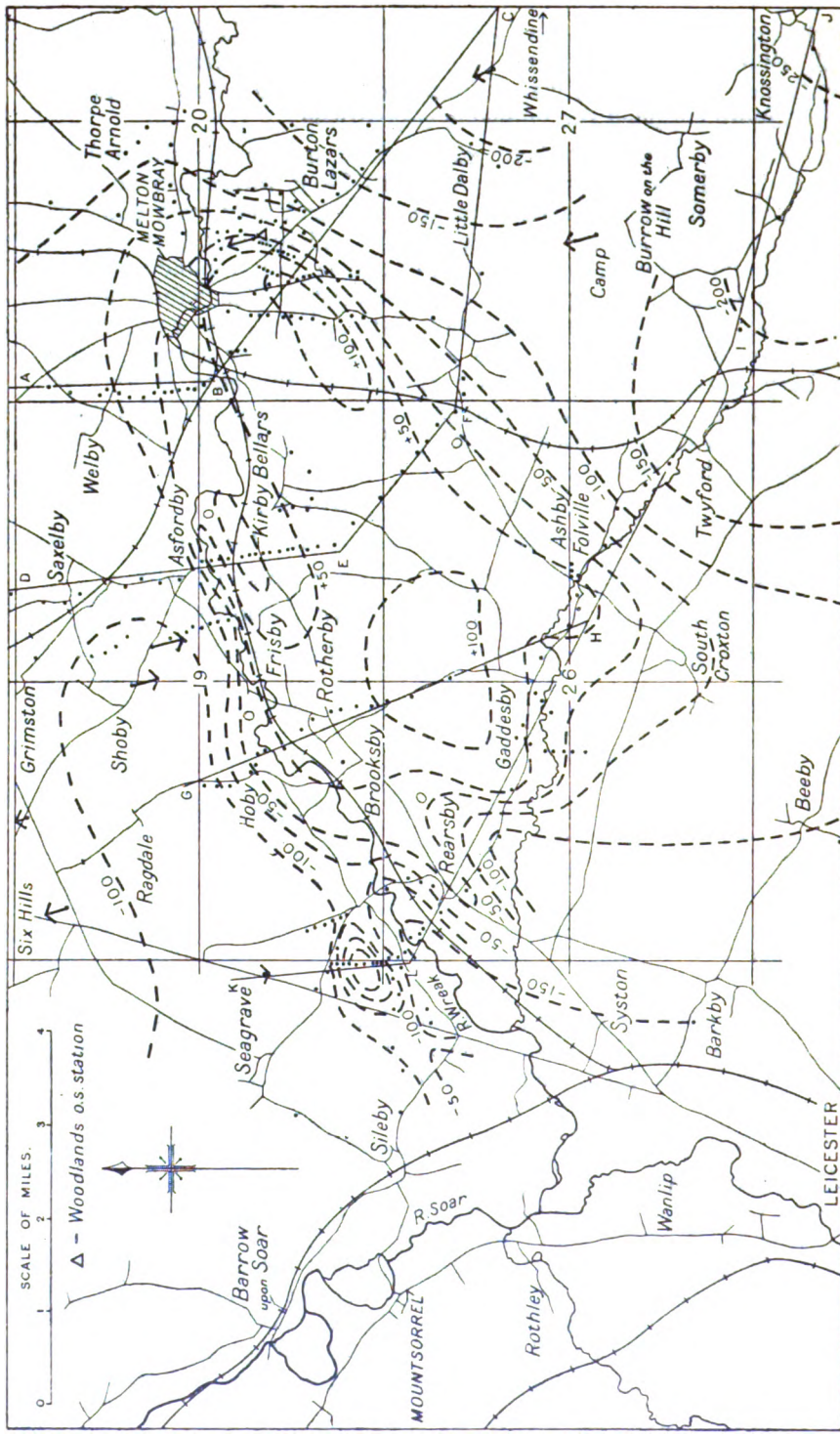

FIG. 2.—*Sketch map of Melton district, with contours showing the difference in vertical force from the Woodlands base. The grid indicates the boundaries of six-inch Sheets* 19, 20, 26 *and* 27 (*Leics.*).

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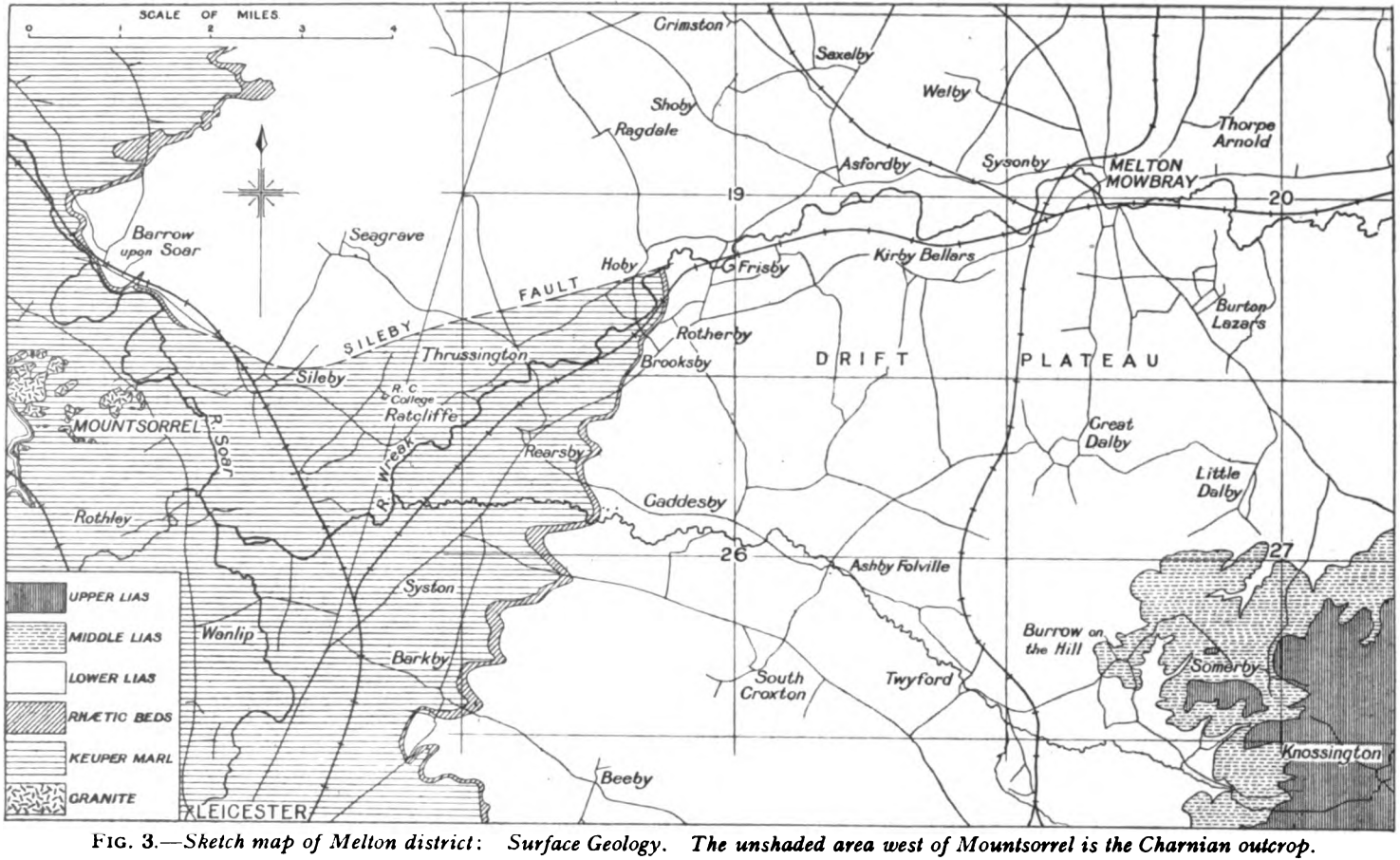

B

FIG. 3.—*Sketch map of Melton district: Surface Geology.* ***The unshaded area west of Mountsorrel is the Charnian outcrop.***

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become, in a roughly circular traverse, Melton +90, Whissendine +62, Burrough Hill +92, Billesdon +90,[1] Keyham +40,[1] Seagrave −2, Six Hills +63, Six Hills +30, Shoby −76, Asfordby −91. The arrows marking these stations in Figure 2 are proportional to these values; they are directed towards the anomaly, except in the case of the two stations near Six Hills, where the northward horizontal force and the rising value of V are no doubt due to the proximity of the Rempstone anomaly which must lie within a few miles to the north-west. No equally simple method is at present available for measuring the westward component, which is known to be very high, for example, at Melton; the resultant horizontal anomaly at these stations could not therefore be ascertained.

GENERAL CHARACTER OF THE MELTON ANOMALY

On reference to the contoured map (Fig. 2) it will be seen that the vertical force exceeds that at the Woodlands base (arbitrarily taken as the zero contour) over a wide area extending south-west of the Woodlands station, and broadening so that the northern margin follows the Wreak valley, while the southern margin extends in a fairly straight line as far as Ashby Folville, where it turns sharply north-west and passes through Gaddesby and Rearsby to join the Wreak at Brooksby. All round this margin the vertical force rises more or less steeply toward the central part of the area, over which it appears to have a fairly uniform value of about +100 γ. On the northern and western margins, at Asfordby, Thrussington and Rearsby, narrow steep ridges of similarly high vertical force appear at distances of a mile or more from the main area, but no corresponding features were observed on the southern margin. Here the force diminishes steadily to values below −200 near Whissendine and Knossington. It may be questioned whether anything resembling a uniform base-line for the country will ever be directly observable, since few areas can be free from irregularities due to the uneven distribution of magnetic rocks at depth. Even at these outlying stations the vertical force is still considerably above several values recorded by Walker (*op. cit.*, p. 58) for stations in the present region (District V), the lowest of these being at Northampton (452 γ below Melton); similarly the gradients are higher than that of the base-surface calculated by Walker (*cf.* p. 7) for the British Isles. Irregular low ridges appear to extend from the main area southwards and towards Burrough Camp, and northwards from Melton, but these are rather sharply differentiated from the principal feature, which may be compared with a steep plateau rising from an undulating plain. Fuller details of one of the narrow steep ridges on the west, that at Thrussington, will be given below.

The cross-section of the 'plateau' is shown in the vertical force profiles given in Figure 4; these exhibit clearly the simple gradient to the south and the steep ridges on the north.

[1] South of the area shown in Figs. 2 and 3.

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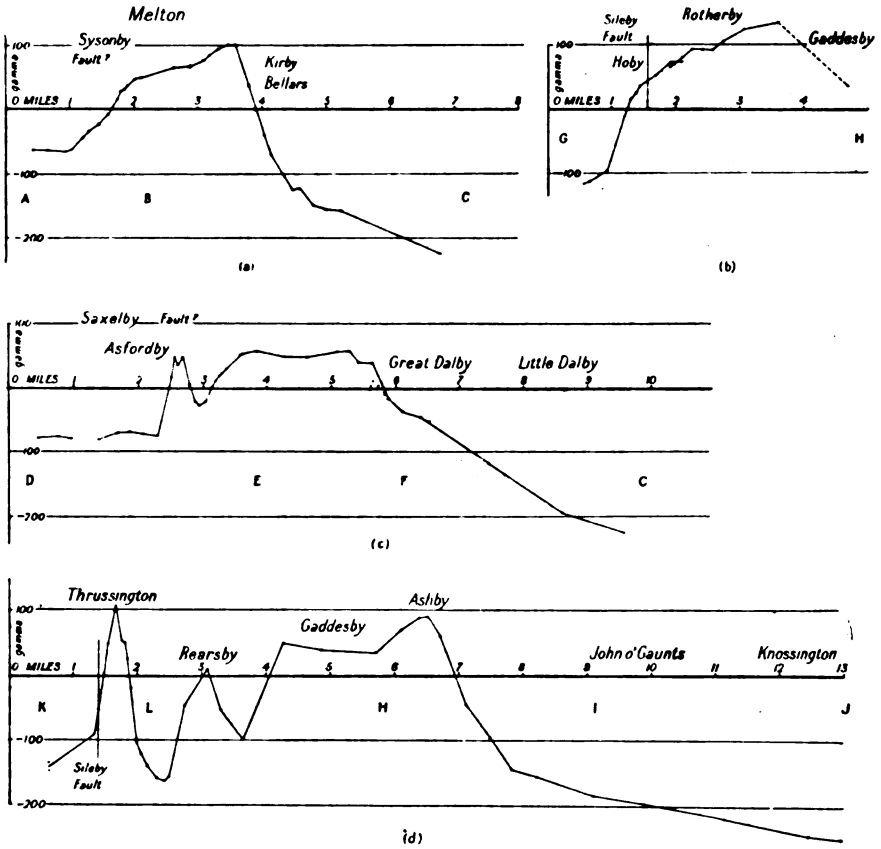

FIG. 4.—*Vertical force profiles across the Melton anomaly.*

(*a*) *Along A B C (Fig. 2), from Sysonby to near Whissendine.*
(*b*) *Along G H (Fig. 2), from Hoby to Gaddesby.*
(*c*) *Along D E F C (Fig. 2), from Asfordby through Great Dalby to near Whissendine.*
(*d*) *Along K L H I J (Fig. 2), from Thrussington, through Ashby Folville to Knossington.*

THE MAGNETIC ANOMALY AT MOUNT SORREL

Measurements by Wilson (Cox, *op. cit.*, p. 83-8) showed that the principal, indeed, almost the only, magnetic rock exposed in this area is the Mount Sorrel granite. The magnetic ridges on the north-west of the Melton anomaly were traced within four miles of Mount Sorrel, and it therefore became of interest to ascertain the vertical force profile over the edge of the known granite, for comparison with those already observed. Accordingly a traverse was made between Sileby Mill and Mount Sorrel including two stations on the granite itself on Castle Hill. The profile (Fig. 5) reveals a very interesting feature. The vertical force does not diminish immediately at the foot of the visible granite hill, but drops steeply at a point

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nearly a quarter of a mile away, in the fields near the River Soar. It would follow that the magnetic rock must continue beneath the Keuper Marl as far as this point. Here the profile is that for a very steep boundary of the magnetic mass at a depth of about 300 feet, and this is apparently the true margin of the Mount Sorrel granite intrusion. Quarrying operations have shown that the visible granite forms a cliff imbedded in the Keuper Marls. The cliff is wind-etched, and must have been cut back for some distance from the original margin of the granite probably near the beginning of Keuper times, thus leaving a bench of granite at a moderate depth below the present land-surface of Keuper Marl. This structure is illustrated in the horizontal section (Fig. 5) and is in complete agree-

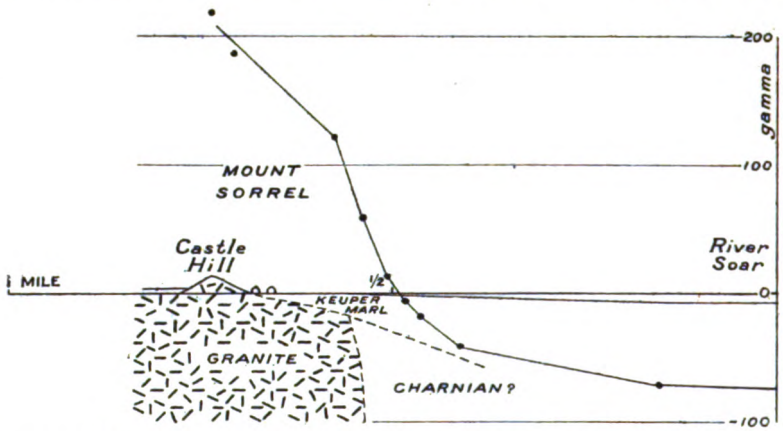

FIG. 5.—*Vertical force profile across the edge of the Mount Sorrel granite, with horizontal section.*

ment with the magnetic observations; it finds a parallel in the known relations of the rocks in the Charnwood district (*cf.* horizontal section, *Mem. Geol. Survey*, Leicester, p. 5). The granite is known to be intrusive in the Charnian rocks at Mount Sorrel and will almost certainly be in contact with rocks of similar age at the concealed margin. The shallow depth of the granite edge implies that these also will directly underlie the Keuper Marl, forming an extension of the Charnian surface in the direction of Sileby.

THE THRUSSINGTON ANOMALY

An extremely well-defined magnetic ridge was observed near Thrussington (Profile d, Fig. 4). This ridge is separated from the main Melton anomaly by low values (−150 γ) in the valley of the Wreak, and observations on the west showed that the anomaly is restricted within a very small area. It was therefore chosen as most suitable for gravitational tests, and a more detailed map was prepared (Fig. 6). A profile across the area from north to south is shown in Figure 7. The structure is simple, and the profile agrees

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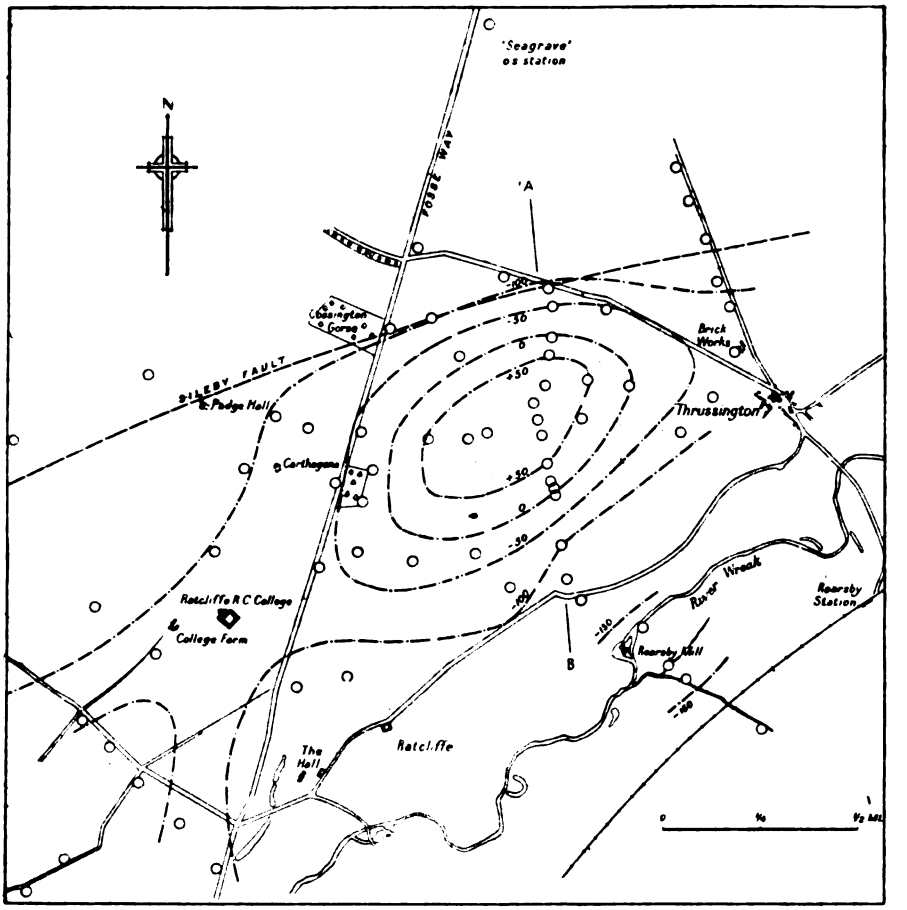

FIG. 6.—*Sketch map of the country near Thrussington, with contours showing the difference in vertical force from the Woodlands base. Circles represent magnetic stations.*

very closely with the curve calculated for a buried granite mass with steep sides and having about the same susceptibility as the Mount Sorrel granite. The edges of this intrusion would lie at a depth of about 500 feet. Near the apex of the profile, however, the vertical force is distinctly higher than that required for a plane granite surface. This is due to some particular detail in structure at a depth commensurate with 500 feet, for the profile shows a definite re-entrant at R in Fig. 7, and can therefore be represented as the sum of the theoretical curve already mentioned and an additional small peak having its apex near S. This local increase in force could be explained if the structure of the granite is regarded as entirely similar to that of the Mount Sorrel mass, *i.e.*, a small ridge or hill rising into the Keuper Marl near the middle of the intrusion, while

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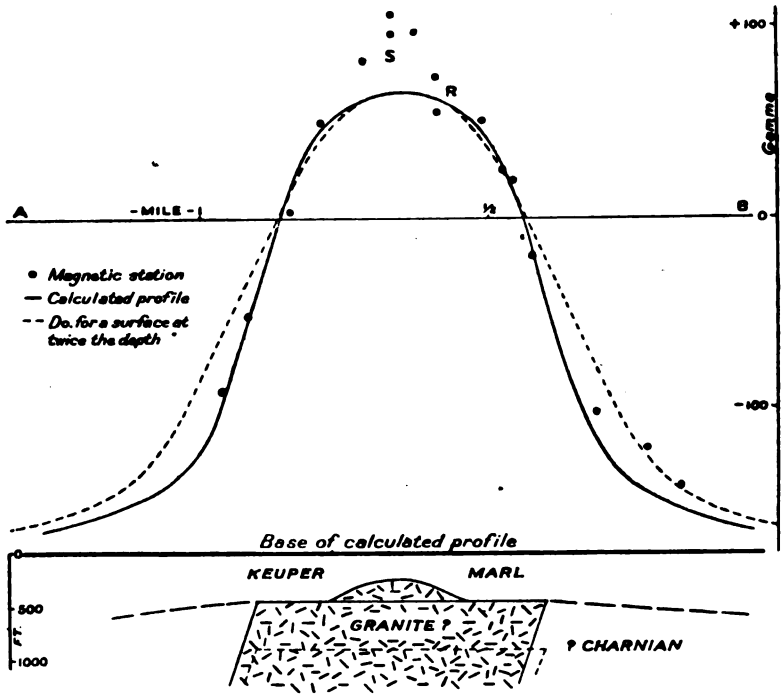

FIG. 7.—*Vertical force profile along the line A B (Fig. 6) across the Thrussington anomaly, with horizontal section.*

the intrusion margins are near the base of the Keuper Marl; on the other hand it might be due to a slightly more magnetic central portion of the rock. Here also the steep sides of the intrusion will probably be in contact with Charnian rocks, which may be expected to form a surface at a depth of about 500 feet. The known thickness of the Keuper Marl implies that the Charnian will be directly covered by the Marl and not by Carboniferous rocks. The following data are available for the Charnian rocks in contact with the Mount Sorrel granite.[1]

Specimen No.	Description and Locality.	Density.	Volume-susceptibility in 10^{-6} C.G.S.
L. 15 ...	Grey Mount Sorrel Granite ...	2·63	62 and 130
L. 9 ...	Blue Swithland Slate	2·78	3·9
L.102 ...	Hornfels, Brazil Wood ...	2·74	3·2
L.112 ...	Do. ...	2·81	6·1

Although a few specimens taken near 'heathen' possess lower susceptibility, there can be no doubt in view of the profile given

[1] Wilson, E. (Cox, *op. cit.*, pp. 84 and 86).

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in Figure 5 that the granite in bulk possesses a susceptibility of the order quoted above. The densities of the neighbouring slates etc., are of great interest, for it will be noted that the difference in density is in the opposite sense from the difference in magnetic permeability, *i.e.*, the granite will behave gravitationally as a lighter rock in a slightly heavier matrix. The small hill postulated at the centre of the intrusion would be in contact, however, with unaltered Keuper Marl and would therefore behave as a heavy mass in a lighter matrix. Magnetically, the form of the profiles is dominated by the difference in susceptibility at the nearly vertical contacts between the granite and the Charnian, but the gravitational effect due to this contact will be relatively small and will be more or less overshadowed by the effect due to the surface of contact with the Keuper Marl, and especially to any hill near the centre of the mass, while a further anomaly will be caused by the Sileby Fault on the northern side of the area.

GEOLOGICAL STRUCTURE

Descriptions of the rocks in this area have already been given in Professor Cox's Report, to which reference should be made, especially to pp. 94-103, dealing with the Melton district, where a full list of the geological maps and Survey memoirs will be found. Attention will at present be confined to those features which have a direct bearing upon the interpretation of the Melton anomaly. The geological map[1] (Fig. 3) shows part of a series of regular parallel escarpments due to the harder beds of the Rhaetic, Lias and Oolite, striking a little east of north across the English Midlands. Each bed remains fairly uniform in general character, though varying somewhat in thickness. The outcrops are remarkably constant in level; that of the Rhaetic being at about 200 O.D. while the Marlstone is at about 500 O.D. A few miles north of Melton the line of these escarpments is interrupted by a spur capped with marlstone, extending westwards as far as Grimston. A parallel deviation occurs in the Rhaetic outcrop to the west. On approaching this spur from the north the outcrops curve gradually to the west, but on the south side of the spur the normal line of the escarpment is resumed abruptly by a displacement of several miles which coincides with a line of faulting known at its western end as the Sileby Fault. Immediately to the south of the dislocation the levels of the Rhaetic at Rearsby (200 O.D.) and in the Melton boring (0 O.D.), and of the Marlstone at Sproxton (east of Melton) are normal, and both escarpments continue southwards in conformity with the line of outcrop north of the spur. At Sproxton the small exposure of Marlstone

[1] With minor changes this is the same as the corresponding area in the map accompanying the above Report. The chief difference in interpretation is that I have given greater importance to the eastward extension of the Sileby Fault, in place of the E.—W. Melton anticlinal structure postulated by Cox. Reference should be made to the general map of the Midland area, and the one-inch geological maps, New Series, Sheets 142 (Melton Mowbray) 156 (Leicester) and 70 (Old Series).

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escarpment is cut off by faults on the east and by Drift on the south, but the underlying Lower Lias is exposed up to 300 O.D. in the small streams flowing down to the Wreak. The Sproxton hill would seem as it were the corner-stone of the undisturbed southern part of the escarpment. Near Hoby the Lower Lias is brought against the Rhaetic, corresponding with a downthrow of about 300 feet to the north ; at Sproxton the Lincolnshire Limestone is thrown down to the level of the Marlstone, again indicating a displacement of over 200 ft. Many smaller faults and folds occur in this area, but the general structure of the Secondary rocks seems to agree with the assumption that the original (now gently eastward-dipping) surface of these rocks has been disturbed by a dislocation along the line of the Sileby Fault, passing through Sileby, Hoby, Asfordby, north of Melton and across the drift-covered valley to Sproxton, where the outcrops are again seen in the main escarpment. On the west the fault is taken up by an oblique cross-fault passing north of the Mount Sorrel granite, and on the east it dies away within the escarpment, often against cross-faults. The downthrow is about 250 feet towards the north, and from this line the strata rise again northwards in a monoclinal fold, regaining their normal level in a distance of about ten miles. Pre-Glacial denudation of this structure has produced the westward-pointing spur of Marlstone and higher beds. Evidence exists that the movements were initiated in pre-Secondary times, for in the Concealed Coalfield of S. Notts, similar faults are known to pass downwards into the older rocks with increased throw (Cox, *op. cit.*, p. 117). In the Melton valley itself an outstanding feature is the Drift plateau which blocks the valley at Melton and in which the present valley of the Wreak is cut, in part along the line of the Sileby Fault. The top of the valley, east of Melton, is relatively free of Drift and resembles a similar area in the Vale of Belvoir to the north of the spur. West of Melton there is a curious general correspondence between the valley and the Sileby Fault : since the Wreak has been cut down to the Lias floor the coincidence may be due to direct control of the stream by the fault. Even more striking is the coincidence between the Sileby fault-line and the northern margin of the magnetic anomaly (see Fig. 2). Only once, at Hoby, does the border of the magnetic anomaly slightly overlap the known course of the fault. In explanation it may perhaps be suggested that a dislocation on this line was present at or before the intrusion of the igneous masses in the Charnian, and that it follows the north wall of a group of typical vertical-sided intrusions. The faults underwent further movement, possibly in Palaeozoic and certainly in later times, when the block of Secondary rocks on the north subsided by about 250 ft. while the rocks on the south maintained their level, perhaps being supported in some degree by the igneous intrusions.

The older rocks.—Within the area of the Melton anomaly the only boring is that at Melton, which penetrated the Rhaetic at about

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O.D. level, and stopped in the Keuper at about —260 O.D. There is a similar boring at Billesdon, south of the area. Evidence from more distant borings and coal shafts has been summarized by Cox (*op. cit.*, pp. 94, 95). Unconformities occur between the Trias, Permian and Carboniferous, and beneath the last no older rocks have been definitely proved except the Pre-Cambrian of Charnwood. The several formations thin westwards and disappear toward the Charnian ridge, but the order of disappearance is uncertain. Rocks of Cambrian type have been proved at Leicester, and the possibility that they form part of the floor of older rocks in other places has been discussed by Cox (*op. cit.*, p. 100) ; in view of the uncertainty on this question the floor has been termed Charnian throughout the present Report.

CONCLUSIONS FROM THE MAGNETIC SURVEY

Reasons have already been given for regarding the Thrussington anomaly as due to a mass of igneous rock forming part of the buried Charnian floor, at a depth of about 500 ft. below the surface. The steep sides of the magnetic profile correspond with the outline of the igneous mass and are due to the sharp angle between the eroded land-surface and the walls of the intrusion. Magnetic ridges of the same kind were observed at Asfordby and Rearsby, but were not so fully mapped. The main Melton anomaly is remarkably similar to these ridges, both in maximum force and in the gradients around its margin. Before the full extent of the anomaly had been mapped it was thought that the high magnetic force might be due to a sill ; the profile for a sill, however, is characterised by a region of negative vertical force beyond the edges of the mass (Fig. 8), and on extending the present traverses into the country south and north of the Melton anomaly no such minimum was observed. On the contrary the force steadily diminished and the profiles agree with those due to a buried surface of magnetic rock at a depth of about 1,200 ft.

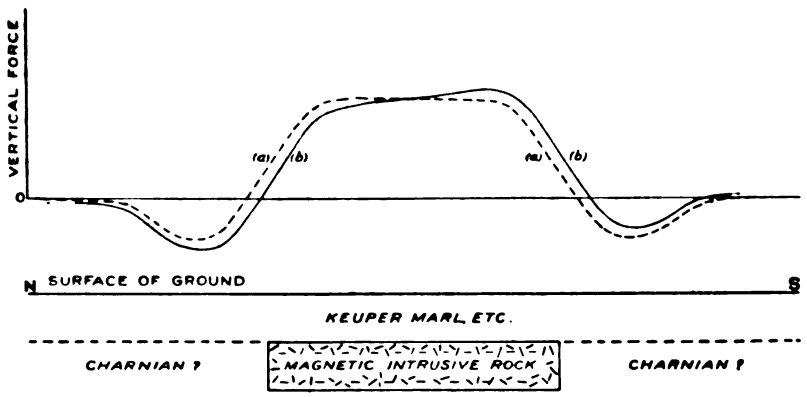

FIG. 8.—*Calculated vertical force profile across a thick sill.*

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and with nearly vertical sides extending downwards to a considerable depth. This structure has the theoretical profile shown in Fig. 9, which may be compared with the observed profiles shown in Fig. 4. It is similar to the Thrussington structure but on a much larger scale and at a greater depth, the gradients at the edges corresponding to a depth of 1,200 ft. instead of 500 ft. To the south of Melton a steeper gradient occurs, but the form of this profile is no longer that for a simple magnetized surface. At the southern corner of the anomaly, at Ashby Folville, the gradients are not so steep, and the depth may be greater.

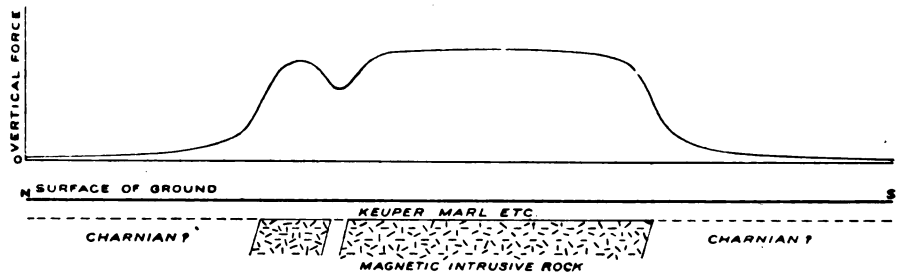

FIG. 9.—*Calculated vertical force profile across a concealed surface of magnetic rock (compare with Fig. 4).*

Over all this area the maximum vertical anomaly is approximately 300 γ. The vertical force above an infinite horizontal magnetized surface is $2\pi k V$ where V is the earth's vertical component (about ·43 C.G.S.); for this mass k is therefore about 110×10^{-5}, a value similar to those for the Thrussington mass and for the Mount Sorrel granite. If it is accepted that all these anomalies are due to similar rock masses, the outline of the anomaly, following approximately the contour —50 in Fig. 2, will be that of the more or less vertical (or northward dipping) marginal walls of an igneous intrusion (possibly granite) in the Charnian. In this case the Charnian floor may be held to extend eastwards at a very moderate depth (about 1,200 ft.) at least as far as Melton Mowbray, a distance of about 12 miles from Mount Sorrel, but it will presumably be lower by at least 250 ft. on the north side of the Sileby Fault. How far the throw of this fault in the Charnian may exceed its value in the Secondary rocks there is no indication, for no well-defined magnetic feature was located on the north side of the fault and consequently no estimate of depth is available.

As regards the rocks covering this floor, there is good reason to expect a normal Secondary succession down to the base of the Trias. In the most southerly section available in the concealed Nottingham Coalfield (Cox, *op. cit.*, p. 99, Fig. 6), from Ruddington to Owthorpe, the Trias with fairly uniform thickness overlies unconformably the Coal Measures, which have a steeper eastward dip; with this as basis various suggestions have been made as to the continuation of the Concealed Coalfield beneath the Melton district.

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In the Melton boring the Rhaetic was proved at about O.D. level; if the total depth of the Charnian floor is taken as about 1,200 ft. below the Drift plateau (at roughly 300 O.D.), there remains a balance of 900 ft. below the Rhaetic of which at least 650 ft. may be expected to be taken up by the Keuper Marls. Even if the Bunter were missing, only the remaining 250 ft. would be available for a possible wedge of Coal Measures or other older rocks; indeed it seems more likely that none of these older rocks are present and that the concealed surface of the intrusion lies near the base of the Trias and is comparable with those at Mount Sorrel and Thrussington. The approximate coincidence between the concealed surface and the probable base of the Trias over so wide an area would be unlikely if the surface were due to an earlier planation of the Charnian beneath the more steeply dipping Coal Measures, while it is readily explained if this part of the Charnian floor has been exposed to the great pre-Triassic (or early Triassic) planation, which transgresses all the formations from the Coal Measures to the Charnian and has left the harder rocks of the latter as wind-etched hills now imbedded in the Keuper Marl. As a result of the present magnetic survey it seems reasonable to conclude that the Coal Measures will be missing beneath the Melton district, at any rate south of the Sileby Fault; and that the Trias rests upon an igneous rock in the Charnian (or Cambrian) floor.

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II.—HORNFELSES FROM KENIDJACK, CORNWALL

BY

CECIL E. TILLEY, PH.D., B.SC., AND
SIR JOHN S. FLETT, K.B.E., F.R.S.

Text-figures 1 to 4

Plates I and II

The metamorphic rocks forming a narrow coastal strip extending from Cape Cornwall northward to Pendeen lie completely within the aureole of the Land's End mass of granite, the boundary of which in this locality runs practically parallel to the coast and about a quarter of a mile or less inland. The rocks of this tract are briefly described in that chapter of the Geological Survey Memoir on the Land's End District (Sheet 358, 1907, pp. 20-39) devoted to the contact altered killas and greenstone surrounding the Land's End Granite. They consist of a mixed series of sediments and dolerites (greenstone) now converted to hornfelses of a considerable range of mineralogical composition. The excellently exposed cliff sections between Cape Cornwall and Pendeen probably provide the finest exposures of contact altered rocks in Cornwall. That part of the area located immediately west of Kenidjack and Botallack is of especial interest on account of the development of hornfelses rich in coarsely crystallized cordierite and containing also the rhombic amphibole, anthophyllite. Rocks carrying cordierite and amphibole were first recognized from this locality by Sir John Flett who has described from the vicinity of Kenidjack Castle hornfelses containing large shining dark patches of cordierite together with abundant acicular amphibole. Of these he writes "no finer cordierite rocks than these are known in Britain, and the presence of hornblende in them lends an additional interest as this mineral is very exceptional in rocks of this group."[1]

It is the object of the following notes to describe more fully the nature of these and related rocks from this locality. The dominant rock types are contact altered greenstones (dolerite hornfelses) rich in green hornblende, and a group of cordierite hornfelses rich in anthophyllite and also containing in part abundant monoclinic ferromagnesian amphibole (cummingtonite).

Greenstones form the dominant rock of the coastal cliffs between Zawn Buzz and Gen and North Zawn, but between these and the granite a zone of cordierite and anthophyllite rocks intervenes and forms the chief rock of the Rifle Ranges. They outcrop along the coast between the North Zawn and Loe Warren. The contact rocks

[1] *Loc. supra cit.*

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south of Zawn Buzz and Gen are obvious sedimentary types in which anthophyllite has not been observed. In addition to the zone of anthophyllite-cordierite rocks on the Rifle Ranges anthophyllite rocks occur interdigitated among the greenstone. Both the greenstone and cordierite-anthophyllite hornfelses are quarried. The two quarries at the seaward end of the path leading from Kenidjack are largely in hornfelsed greenstones containing bands and lenses of cordierite-anthophyllite rock, while a quarry immediately above North Zawn is developed in anthophyllite-cordierite rocks similar to those outcropping on the Rifle Ranges. The greenstones proper call for little description as they have been exhaustively described in the Survey Memoir. They are essentially hornblende-plagioclase rocks but carry sphene and ilmenite, while epidote, diopside, biotite, axinite, and grossularite are less common constituents.

Normal sediments now converted to hornfelses form a zone at the immediate contact with the granite. These are well seen at Priest's Cove and at Cape Cornwall. In the area now dealt with (Fig. 1) they form the promontory south of Zawn Buzz and Gen, and the coast

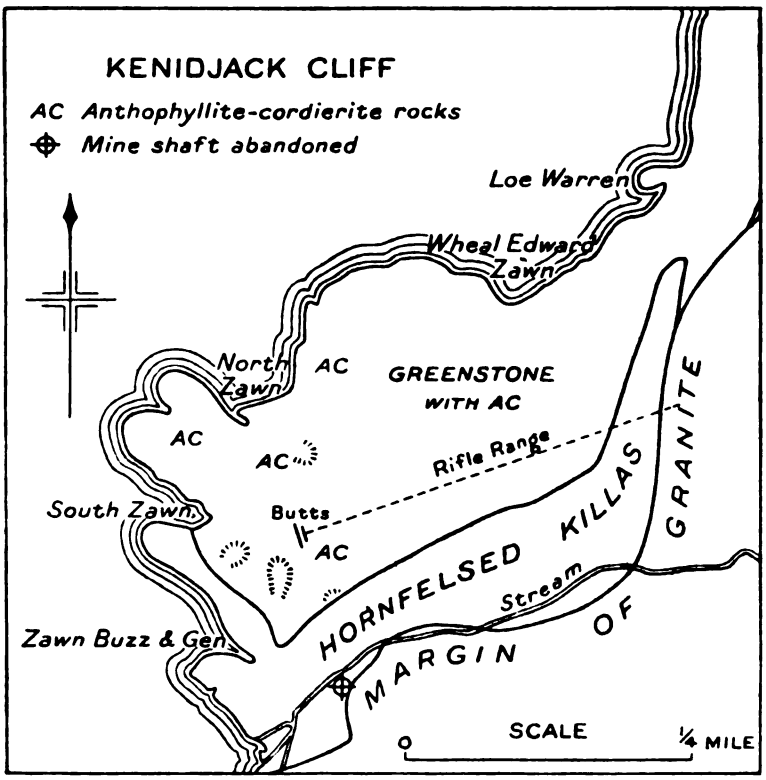

FIG. 1.—*Sketch map showing the coast near Kenidjack, Cornwall.*

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immediately north of this to South Zawn, their boundary with the greenstones extending inland to Wheal Edward. Near the Crowns a narrow strip of hornfelses is enclosed by greenstones, and smaller patches of sediments occur among the greenstones in this area.

The rocks are essentially argillaceous and siliceous sediments, and have in the field often a striped appearance due to variation in composition and the presence of thin quartz veins. These hornfelses include andalusite-cordierite, and cordierite-biotite assemblages. At Priest's Cove near Cape Cornwall highly aluminous types occur, the principal assemblage being a cordierite-andalusite-corundum (sapphire) hornfels. Evidence of pneumatolysis is frequently seen in the abundance of white mica and tourmaline in these altered rocks.

The distribution of the anthophyllite and cummingtonite rocks of the Kenidjack area can be seen from the accompanying map (Fig. 1). They are most closely associated with the greenstones and do not occur within the main body of the hornfelsed sediments already referred to. The principal variety is a cordierite-anthophyllite assemblage as exposed on the Rifle Range. The typical rocks are grey black in colour ; cordierite is readily distinguished, appearing in dark resinous patches usually ovoid in section but sometimes highly irregular, the areas between the cordierite patches being occupied by anthophyllite with which a variable amount of biotite is associated. These rocks frequently develop on weathered surfaces a knotted appearance, the knots being formed of rounded or ellipsoidal crystals of cordierite reaching up to one inch in their longer diameter, and protruding from the weathered surfaces. Remarkable examples of such knotted hornfelses form conspicuous crags on the coast immediately north-east of North Zawn. Less commonly the excrescences on weathered surfaces are made up of anthophyllite. In these the anthophyllite is of coarser grain and occurs as bunches of radiating prisms reaching three-quarters of an inch in length, while the cordierite, though abundant, is less conspicuous, occurring interstitially in irregular layers. Examples of such ' starstones ' occur along the cliffs immediately below the Wheal Edward.

PETROGRAPHY OF THE HORNFELSES

The rocks developing anthophyllite or cummingtonite include a varied group of hornfelses, which may be petrographically subdivided as follows :—

(*a*) Anthophyllite-cordierite rocks.

(*b*) Anthophyllite-cordierite-spinel-diaspore rocks.

(*c*) Anthophyllite-plagioclase-spinel-diaspore rocks.

(*d*) Cummingtonite-cordierite rocks.

(*e*) Cummingtonite-plagioclase rocks.

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to which may be added two distinctive types of pneumatolytic origin,

(*f*) Tourmaline-anthophyllite-[spinel] rocks.

(*g*) Chlorite (clinochlore)-anthophyllite-[spinel] rocks.

This list does not exhaust the range of variation developed among these hornfelses, but the other assemblages noted can be considered as variants of one or other of the above types, and are referred to in the petrographic description that follows.

(*a*) **Anthophyllite-cordierite hornfelses.** (Plate I, Figs. 1, 2, 6.)

The constituents of these hornfelses are anthophyllite, cordierite, biotite, ilmenite, and accessory apatite and zircon. Quartz is present in some types but is usually absent. An analysis appears in Table 1, column 1. The large cordierite crystals are xenoblastic, usually partly pinitized. They show multiple twinning on 110 revealed in sectors or striped crystals. The mineral is rich in inclusions, biotite in small pale yellow flakes, anthophyllite in radiating needles, and ilmenite in streams of small granules. These streams pass through the cordierite crystals independent of their orientation. The areas between the cordierite crystals are filled with anthophyllite and variable amounts of biotite. The anthophyllite in these areas as well as in the cordierite is markedly idioblastic. The prismatic crystals are usually bounded by 110; less commonly 010 faces occur in addition. They are colourless in thin section, but megascopically are greyish to grey brown. In thicker sections a slight pleochroism may be visible, Z = grey brown, X = pale yellow. The anthophyllite is optically positive, Z = c, Y = b, X = a. The refractive indices are $\alpha = 1{\cdot}645$, $\gamma = 1{\cdot}665$. Small halos around zircon crystals are of a greenish brown tint. This anthophyllite may be compared with a pale anthophyllite from Träskböle (Orijärvi) with very similar indices ($\beta = 1{\cdot}653$, $\gamma = 1{\cdot}667$) and containing 7·35% alumina, 22·18% ferrous oxide and 16·64% magnesia.

Some cummingtonite is present in a number of these rocks, and is especially apt to occur in radiating patches and veinules cutting through the rock mass (see pp. 30, 31).

The biotite associated with the anthophyllite is always of a pale yellow tint. Ilmenite occurs in section as granules or laths with rounded terminations. It appears in streams passing through the anthophyllite crystals. The parallel disposition of these streams is independent of the orientation of the cordierite and anthophyllite crystals and is clearly a relict texture surviving the thermal metamorphism. Finely granular plagioclase is present in some bands in place of cordierite. It is not, however, an essential constituent of the typical anthophyllite-cordierite hornfelses.

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(*b*) **Anthophyllite-cordierite-spinel-diaspore hornfelses.**[1]

(*c*) **Anthophyllite-plagioclase-spinel-diaspore hornfelses.**

Many of the anthophyllite rocks of Kenidjack carry green spinel; quartz is therefore never present in such types. They resemble the anthophyllite-cordierite rocks already described in many particulars; frequently, however, the anthophyllite is coarser grained. Some varieties contain plagioclase in place of cordierite (type *c*). The dominant minerals are anthophyllite, cordierite, plagioclase, biotite, green spinel, diaspore, cummingtonite, ilmenite, magnetite, apatite and zircon. (Plate I, Figs. 3, 4).

The coarse-grained anthophyllite is a type richer in ferrous oxide than that characteristic of group (*a*), as is indicated by its higher refringence—$\alpha = 1{\cdot}656$, $\gamma = 1{\cdot}677$. We may compare these values with those of an anthophyllite from Orijärvi which has $\beta = 1{\cdot}662$, $\gamma = 1{\cdot}676$ and contains 26·11% ferrous oxide, 12·66% magnesia and 7·63% alumina.

TABLE I.

	[1]	[2]	[3]
SiO_2	47·07	48·00	48·00
Al_2O_3	20·20	18·62	24·74
Fe_2O_3	0·00	1·07	0·18
FeO	12·73	16·18	11·03
MgO	10·09	11·85	9·94
CaO	2·14	0·64	0·99
Na_2O	1·48	0·23	0·84
K_2O	1·97	0·01	1·47
H_2O-	0·16	1·50	0·06
H_2O+	1·50		0·97
TiO_2	2·12	2·06	0·99
P_2O_5	0·12	0·09	0·06
MnO	0·11	0·13	0·24
FeS_2	0·47	0·15 (Fe_7S_8)	0·59
Cr_2O_3	0·02	0·04 (V_2O_3)	0·21
Li_2O	0·03		0·06 (BaO)
	100·21	100·57	100·37

[1] Anthophyllite-cordierite Hornfels, Carn Kenidjack; with biotite, plagioclase, ilmenite, and some cummingtonite. *Anal.* B. E. Dixon.

[2] Anthophyllite-cordierite Hornfels, Träskböle, Orijärvi, Finland (*Bull. Comm. Géol. Finlande*, 1914, No. 40, p. 171).

[3] Cordierite Norite, Huntly, Aberdeenshire (*Quart. Journ. Geol. Soc.*, 1914, p. 289).

[1] Assemblages of this composition do not appear to be recorded in the literature. It is therefore of interest to note that a specimen of gedrite rock from the Héas valley, Gèdres, Pyrenees, is closely similar in composition. A thin slice cut from a rock presented by Professor Lacroix from this locality, is seen to be composed of gedrite, biotite, cordierite, clinochlore, apatite, magnetite, green spinel, corundum and diaspore. The spinel and diaspore form aggregates as in the Cornish rocks, but in this case the diaspore is developed from the corundum. The clinochlore is of the same type as that appearing in the Kenidjack rocks. The Gèdres rock is described by Lacroix (*Compt. Rend.* 1886, vol. 102, p. 1331) as containing in addition to biotite and green spinel numerous zircons and blue corundum. In the slice now examined, the highly birefringent grains are, however, seen to be crystals of diaspore.

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The spinel is a green isotropic pleonaste forming clots up to ¼-inch or more in diameter, both within the large cordierite crystals and associated with the anthophyllite. These clots consist of rounded grains of spinel or else idioblastic octahedra. Almost invariably associated with the spinel and usually forming the core of the clots is idioblastic diaspore. The mineral occurs in rhombic crystals flattened parallel to 010, the cleavage plane. It is colourless, of high relief and high birefringence (·048). The elongation is +, and the optic axial plane parallel to 010; optically positive, with an axial angle near 90°. It is in every sense a primary metamorphic mineral. Corundum is never present in these rocks. The diaspore may contain enclosures of ilmenite. Some varieties of anthophyllite rocks containing spinel have little or no cordierite, but are rich in biotite; on the other hand anthophyllite may diminish in amount giving a type consisting of biotite, cordierite, ilmenite, spinel and diaspore.

The second chief type of anthophyllite rock is one containing abundant plagioclase as the colourless constituent. Cordierite is then absent or present in minor amount only. The plagioclase is a labradorite forming a mosaic of untwinned grains, amongst which some granular cordierite may appear. Cummingtonite usually occurs subordinately in these rocks, either as independent prisms or in parallel growth with anthophyllite. In the latter case the core of the prism is usually cummingtonite with oblique extinction. Similar homoaxial growths of anthophyllite and cummingtonite have been described by Eskola from the Orijärvi region.

An interesting rock type which may be referred to here is one containing green hornblende in association with green spinel and diaspore. It shows obvious relationship to the greenstone hornfelses of the Kenidjack area, in consisting of plagioclase and green hornblende, the amphibole occurring in radiate tufts and aggregates in much the same way as cummingtonite and anthophyllite. This amphibole is distinguished from cummingtonite by its colour, and by its optically negative sign. Scattered through the rock are spinel and diaspore in irregular areas as in the anthophyllite-bearing rocks (Plate II, Fig. 5).

(*d*) Cummingtonite-cordierite hornfelses.

(*e*) Cummingtonite-plagioclase hornfelses.

(Plate II, Figs. 1, 2, 3).

Rocks in which cummingtonite is an important constituent are not rare in the Kenidjack aureole. As already noted, this mineral may appear as a minor constituent in the anthophyllite-cordierite rocks, but in the rocks now to be described it is the dominant amphibole. Some of the rock types are not megascopically distinguishable from the anthophyllite-cordierite hornfelses. Others, however, are distinctive. In addition to cummingtonite appearing

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as a constituent of the rock itself, the mineral also occurs in veins and strings cutting the hornfelses. These veins, grey brown to clove brown in colour, reach up to half an inch in width and are frequently irregular. They are sometimes accompanied by quartz, the habit of the cummingtonite being acicular and radiate. Some of the hornfelses are distinctly banded (Fig. 2). In a typical example the rock consists of alternating layers black, bluish grey, and clove brown in colour. In thin sections the black bands are seen to be rich in pale yellow biotite and contain scattered needles of anthophyllite and streams of ilmenite ; the bluish grey bands are rich in plagioclase with minor biotite, anthophyllite, cummingtonite, and ilmenite streams, while the clove brown bands are essentially built of cummingtonite, appearing colourless or pale brownish in section, often in radiating masses and with bent or curved prisms. The whole assemblage forms a cordierite-cummingtonite-anthophyllite-plagioclase-biotite rock (Plate II, Fig. 1). It is noteworthy that the

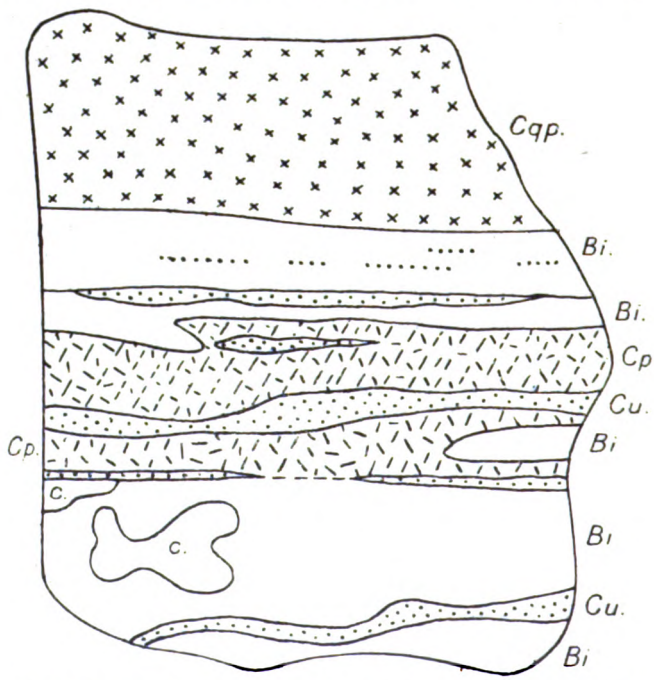

FIG. 2.—*Banded hornfels from North Zawn Quarry, Kenidjack (natural size).*

Cqp. Band built up of cummingtonite and quartz, with minor bands of fine-grained plagioclase with tufts of cummingtonite.

Bi. Band rich in biotite with accessory cordierite, some ilmenite and prisms of anthophyllite.

Cp. Band essentially of fine-grained plagioclase, some ilmenite and tufts of anthophyllite and cummingtonite.

C. Ovoid crystals of cordierite with enclosures of anthophyllite, fine scales of biotite and orientated streams of ilmenite.

Cu. Band composed wholly of tufted cummingtonite.

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streams of ilmenite already referred to run parallel to the bands themselves. The usual rock type is a cummingtonite-cordierite rock containing variable amounts of anthophyllite, biotite, ilmenite, quartz and granular plagioclase, the latter in association with the cordierite. The cummingtonite forms typically grey brown, lenticular aggregates with a marked radiate disposition of the fibres, separated by areas of cordierite, the borders of the aggregates being often fringed with ilmenite granules which conform generally to the linear arrangement noted. Biotite may be very sparingly present. The cummingtonite is not noticeably pleochroic. Its habit is similar to that of the anthophyllite, acicular prisms bounded by 110. The sign and elongation are positive, optic axial plane parallel to 010 and the extinction $Z \wedge c = 19°$. The refractive indices are $\alpha = 1{\cdot}643$, $\gamma = 1{\cdot}670$.

An analysis of the cummingtonite separated from a vein of cummingtonite in a cummingtonite-biotite-cordierite hornfels is given below (Table 2, column 1). The analysis may be compared with that of an Orijärvi cummingtonite (Table 2, column 2) which has closely comparable magnesia and ferrous oxide contents and refractive indices $\alpha = 1{\cdot}641$, $\gamma = 1{\cdot}668$. The analysis of the Kenidjack cummingtonite agrees closely with the formula $(RO.R_2O)$, SiO_2 with some R_2O_3 (Table 2, column 3a).[1]

TABLE 2.

	[1]	[2]	[3]	[3a]	
SiO_2 ...	53·12		50·99	8809	
Al_2O_3 ...	2·78		3·78	272	(Si, Ti) O_2 8835
Fe_2O_3 ...	0·25		0·85	16	R_2O_3 288
FeO ...	22·46	21·47	21·70	3126	$RO.R_2O$ 8835
MgO ...	15·46	17·85	18·61	3824	with residue
CaO ...	2·26	0·54	—	403	of 0·75% H_2O
Na_2O ...	—	0·27	0·24		Molecular %
K_2O ...	—		0·31		Fe SiO_3 34·8
H_2O+ ...	3·33		2·77	1848	Mg SiO_3 42·7
MnO ...	0·27		0·18	38	Ca SiO_3 4·4
TiO_2 ...	0·21		0·02	26	Mn SiO_3 0·4
					H_2 SiO_3 16·0
					$Al_2O_3+Fe_2O_3$ 1·6
	100·14		99·45		
Refraction	γ1·670 α1·643	γ1·668 α1·641			

[1] Cummingtonite from Cummingtonite Hornfels, Rifle Ranges, Kenidjack.

[2] Cummingtonite from Cummingtonite-plagioclase rock, Träskböle (Orijärvi), *op. cit.*, p. 183.

[3] Cummingtonite Skarn (wholly of cummingtonite), Odalfältet, Persberg, Sweden, *Geol. För. Förh. Stockholm*, vol. 36, 1914, p. 454.

[3a] Molecular composition of [1] expressed as $[(RO.R_2O).(Si\ Ti)\ O_2\ R_2O_3]$.

[1] *cf.* the chemical and optical data on the cummingtonite-grünerite series assembled by N. Sundius (*Geol. För. Förh. Stockholm*, vol. 46, 1924, pp. 154-167).

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Plagioclase (andesine to labradorite) is frequently an important constituent of the cummingtonite-bearing rocks (type *e*). It is always minutely granular and rarely shows signs of twinning. Quartz appears as a more frequent constituent of the cummingtonite-bearing hornfelses than of the anthophyllite-bearing types. An analysis of a cummingtonite-cordierite-plagioclase hornfels is given in Table 3, column 4.

TABLE 3.

	[4]	[5]	[6]	[7]
SiO_2 ...	48·87	46·77	50·99	53·40
Al_2O_3 ...	16·71	?	15·18	16·33
Fe_2O_3 ...	0·13	0·94	1·87	0·78
FeO ...	12·85	16·34	8·09	9·72
MgO ...	9·60	?	10·00	7·46
CaO ...	5·42	5·44	8·60	6·16
Na_2O ...	1·61	0·68	2·67	3·50
K_2O ...	0·27	1·42	0·38	0·04
H_2O- ...	0·07	1·57	0·10	0·52
H_2O+ ...	0·99		0·95	
TiO_2 ...	2·71	0·88	0·65	1·75
P_2O_5 ...	0·50	0·20	—	
MnO ...	—	0·33	0·18	0·23
CO_2 ...	0·07		—	
Cr_2O_3 ...	0·01		0·08	
S ...		0·13	0·08	
	99·81		99·82	99·89

[4] Cummingtonite-anthophyllite-cordierite-plagioclase Hornfels, coast between North Zawn and Wheal Edward Zawn, Kenidjack (with ilmenite, biotite). *Anal.* B. E. Dixon.

[5] Cummingtonite-plagioclase rock (60% cummingtonite, 35% plagioclase, 5% biotite), Falun Mine, Sweden, *Geol. För. Förh.*, 1926, vol. 48, p. 69.

[6] Cummingtonite-bearing Amphibolite, Orijärvi, Finland. P. Eskola, *Bull. Comm. Géol. Finlande*, 1914, No. 40, p. 109 (plagioclase 36%, green hornblende and cummingtonite 64%).

[7] Cummingtonite Amphibolite, Orijärvi, Finland. P. Eskola, *op. cit.*, p. 223 (plagioclase 49%, cummingtonite 48%, ilmenite 3%).

Pneumatolytically altered anthophyllite-cordierite rocks.—Two types of pneumatolytic alteration of these hornfelses are characteristic of the Kenidjack area.

(*a*) Tourmalinization—(Plate II, Fig. 4).

In this case the rock is converted into a tourmaline hornfels, the tourmaline[1] forming largely at the expense of cordierite. The mineral forms zoned crystals of brown to brown-green colour and encloses numerous radiating needles of anthophyllite. Green spinel, diaspore and magnetite represent residuals unaffected by pneumatolysis, while the content of apatite is increased.

[1] This tourmaline has $\omega = 1{\cdot}646$, $\varepsilon = 1{\cdot}625$, while the pleochroism is ω = brown to greenish brown, ε = light yellow to colourless. These values point to a tourmaline with a significant magnesia content.

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(*b*) Chloritization—(Plate I, Fig. 5).

In this type chlorite takes the place of cordierite. It is of clinochlore type, colourless to greyish in thin section, multiply twinned on the mica law, biaxial with small optic axial angle, elongation negative, optically positive, R.I.= 1·59, D.R.= ·008. Like the tourmaline it contains radiate acicular anthophyllite, green spinel and diaspore. These pneumatolytic effects, as noted above, have clearly affected rocks rich in cordierite. The chlorite is distinct from that developed in the normal alteration of cordierite. Examples of such pneumatolytic clinochlore occur also among some of the greenstone hornfelses. An analysis of an anthophyllite-cordierite-(clinochlore)-spinel hornfels is given below (Table 4, column 8).

TABLE 4.

	[8]	[9]
SiO_2	33·58	31·46
Al_2O_3	11·79	15·46
Fe_2O_3	11·27	4·23
FeO	17·50	18·02
MgO	15·55	12·38
CaO	0·89	0·72
Na_2O	0·60	0·39
K_2O	0·32	0·42
H_2O-	0·13	9·80
H_2O+	4·60	
TiO_2	2·96	0·76
P_2O_5	0·36	0·20
MnO	0·21	0·37
Co_2	nil	—
Cl	0·02	FeS_2 5·56
F	nil	$CuFeS_2$ 0·81
Cr_2O_3	nil	
(NiCo)O	nil	
	99·78	100·58

[8] Anthophyllite-cordierite-(clinochlore)-spinel-diaspore Hornfels, Inner Quarry, Kenidjack; with magnetite, ilmenite, apatite and biotite. *Anal.* R. Sutcliffe.

[9] 'Sköl' from the Falun Mine, Sweden. H. Sjögren. *Geol. För. Förh. Stockholm*, 1926, vol. 48, p. 70.

ORIGIN OF THE HORNFELSES

In order to discuss the origin of the anthophyllite and cummingtonite rocks, it will be necessary to enter more closely into the evidence provided by the chemical analyses, and field and microscopic study.

The three available analyses of these rocks show quite clearly that they are of an exceptional character, the principal features of which are the abnormally high percentages of magnesia and iron oxide. Analysis 1, Table 1, of the anthophyllite-cordierite hornfels shows these characters combined with high alumina and low alkalis

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and lime. Analysis 8, Table 4, is even of more exceptional character, no less than 44·32% of the rock being made up of iron oxides and magnesia. These two analyses depart widely both from the range of composition of normal sediments and of igneous rocks. Analysis 4, Table 3, of the cummingtonite-cordierite-plagioclase hornfels is less abnormal, and as seen from the analyses with which it is tabulated, is closer to that of basic igneous rocks. The values for soda and lime are, however, noticeably low.

The abnormality of these analyses may be graphically represented in triangular plots as seen in Figs. 3 and 4.

In Fig. 3, the variables are taken as K_2O. Al_2O_3, MgO+FeO and Al_2O_3 (O, S and K respectively). In this diagram the fields of

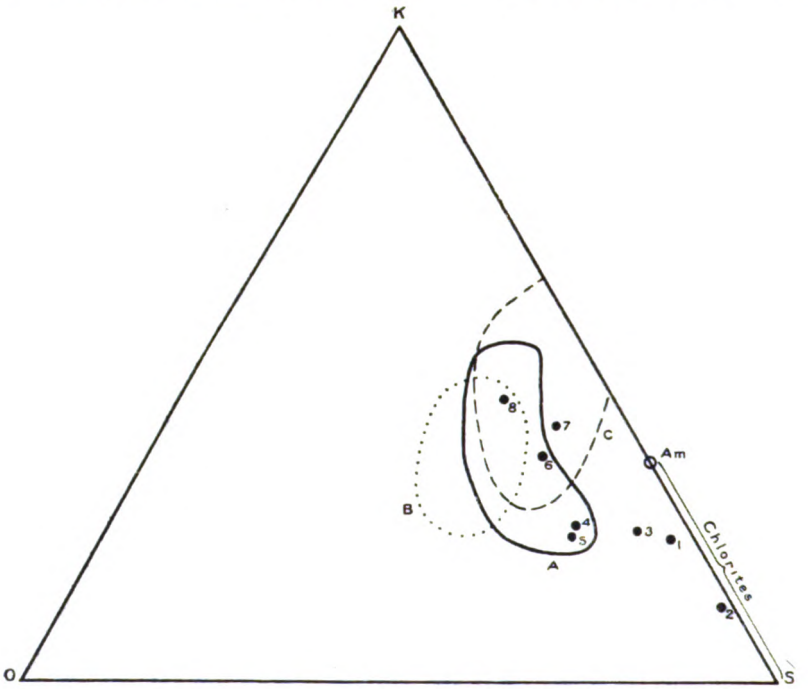

FIG. 3.—*Chemical characteristics of slates, phyllites, etc.*

The abnormal composition of the anthophyllite-cordierite rocks is well revealed in the plot of analyses in Fig. 3 *in which the variables* K_2O Al_2 O_3, MgO+FeO and Al_2 O_3 *are represented by* O, S, *and* K *respectively. The fields* A, B *and* C *represent the concentration fields of slate, mica schists and chloritoid schists respectively.*

Am=*composition of amesite (end member of chlorite group).*

Points 4 *and* 5 *represent analyses of cordierite-hypersthene hornfelses (Kristiania and Umptek); points* 6, 7, 8 *analyses of cordierite-spinel-(corundum) hornfelses (Comrie; Land's End; Ascutney Mt., Vermont); while* 1, 2 *and* 3 *represent analyses of cordierite-anthophyllite hornfels (Orijärvi), cordierite-anthophyllite-spinel-diaspore hornfels (Kenidjack), cordierite-anthophyllite hornfels (Kenidjack).*

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slates, mica schists and chloritoid schists are indicated (*cf. Geol. Mag.*, 1925, p. 363). The points 3 and 2 represent analyses 1 and 8 (Tables 1 and 4). It is seen that they fall well without the fields for normal sediments. For comparison the analyses of some highly argillaceous and magnesian sediments are plotted, points 6, 7 and 8 (cordierite-spinel-corundum hornfelses) and points 4 and 5 (cordierite-hypersthene hornfelses). These, however, fall within the sediment fields.

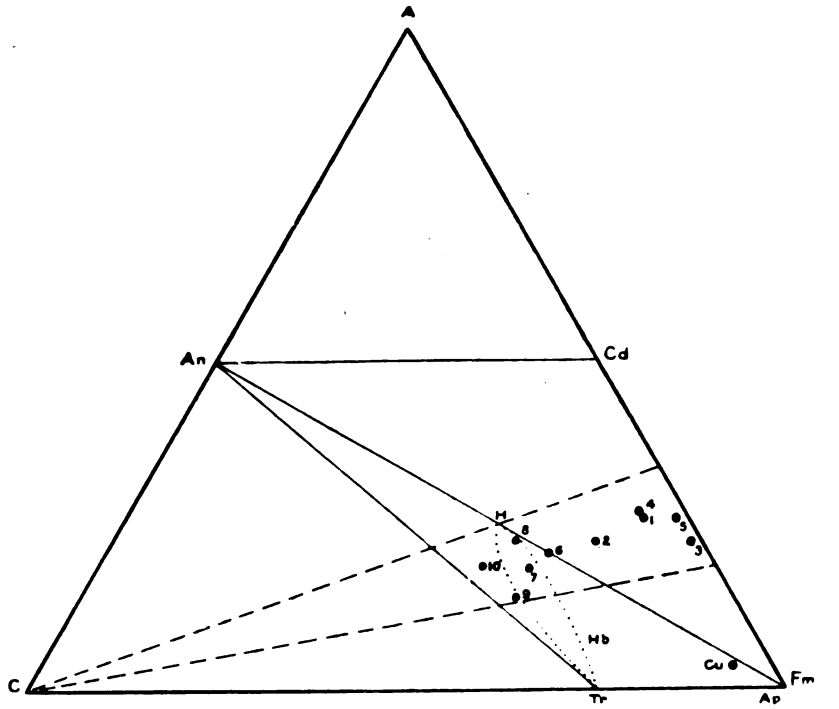

FIG. 4.—*Chemical characteristics of dolerites and greenstones.*

Plot of analyses to show the relationship of the anthophyllite cummingtonite rocks of Kenidjack to similar rocks of the Orijärvi region, and to normal basaltic or doleritic rocks and their metamorphosed equivalents.

1-3, *Anthophyllite-cummingtonite rocks of Kenidjack* (*analyses* 1, 4 *and* 8 *respectively, pp.* 28, 32, 33).

4-5, *Anthophyllite rocks of the Orijärvi region* (*Bull. Comm. Géol. Finlande*, 1915, *No.* 44, *pp.* 65-66).

6-7, *Cummingtonite amphibolites, Orijärvi region* (*ibid.*, p. 66).

8-9, *Greenstones of the Newlyn Quarries, Cornwall* (*Geol. Land's End District, Mem. Geol. Surv.*, 1907, *p.* 35).

10, *Hornblende schist, Meneage, Cornwall* (*Geol. Lizard and Meneage, Mem. Geol. Surv.*, 1912, *p.* 48).

10, *Average plateau basalt* (*Proc. Amer. Acad. Arts & Sciences*, 1925, *vol.* 60, *p.* 73).

$A = [Al_2O_3 - (K_2O + Na_2O)]$, $C = [CaO]$, $Fm = [FeO + MgO - TiO_2]$.

An = *anorthite*, Cd = *cordierite*, Ap = *anthophyllite*, Hb = *field of hornblendes*, Cu = *analysed cummingtonite p.* 31.

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As the cummingtonite-cordierite-plagioclase rock analysed contains a significant percentage of lime (5·42) it is not plotted on this diagram. The plot is sufficient to show that if these rocks represent original sediments, they do not come within, or even close to the field of normal sediments. The analyses, however, may be plotted on a second diagram in which the variables utilized are $Al_2O_3 - (K_2O + Na_2O)$, CaO and $(FeO + MgO - TiO_2)$, = A, C, Fm respectively.

All three Kenidjack analyses can now be plotted and are represented in the points 1, 2 and 3 (Fig. 4).

They may be compared with those of basic igneous rocks, dolerites, basalts and their metamorphosed equivalents—points 8, 9 and 10, 10 representing the average of a series of analyses of plateau basalts. The field of basic igneous rocks of doleritic composition lies in fact to the left of the line An-H-Tr, with 10 as approximate centre. Here also are plotted the analyses of cordierite-anthophyllite rocks from the Orijärvi region (points 4 and 5), and of cummingtonite-bearing amphibolites from the same area (points 6 and 7).

We may sum up the chemical characters as follows :—

The anthophyllite-cordierite and spinel rocks have no counterpart among normal sediments or igneous rocks, while the plagioclase-rich type is more closely related to doleritic rocks, but still shows abnormalities—this is revealed by the plotted position of 2 and also 6—a cummingtonite-plagioclase rock from the Orijärvi area.

We are now in a position to discuss these rocks from a genetic standpoint, having referred to their chemical characters. In turn four hypotheses will be considered. The rocks may be considered as having arisen by the metamorphism of

(*a*) Sediments abnormally rich in chloritic material.

(*b*) Sediments metasomatically affected by introduction of magnesia and iron oxides.

(*c*) Mixed rocks formed by assimilation of aluminous sediments by the doleritic intrusions.

(*d*) The original doleritic intrusions which had been subject to extensive decomposition by atmospheric weathering in which lime and a large part of the alkalis—especially soda, had been removed.

The manner of occurrence of the anthophyllite and cummingtonite rocks in the field is clearly evidence of first importance in discussing their genesis. Their distribution (Fig. 1) is such that they must be considered as most intimately associated with the greenstones. They do not occur within the main body of the hornfelsed sediments, nor can they be seen to pass by gradation into normal sediments. On the other hand at numerous points in the area these rocks can be seen intimately associated with the greenstones and merging into them. This feature is well observed on the steep path leading to the Crowns, on the promontory north of Zawn a Bal, in North Zawn quarry, and on the Rifle Range near the Butts above the inner quarry at Kenidjack. The inner quarry itself is cut in greenstones, which in their upper part pass into coarse-grained anthophyllite-spinel

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rocks and into anthophyllite-cordierite rocks like those of the Rifle Range.

The petrographic description of these rocks has already indicated that a considerable range of composition is revealed among them. At the one extreme come the anthophyllite-cordierite rocks with ilmenite and biotite, but practically devoid of plagioclase felspar, while at the other extreme we have cummingtonite-(anthophyllite)-plagioclase rocks devoid of cordierite but sometimes containing spinel and diaspore. There are intermediate varieties with varying quantities of plagioclase and cordierite.

This range of composition may be summarized as follows :—

{ anthophyllite, cummingtonite } cordierite
passing by decrease of SiO_2 into
{ anthophyllite, cummingtonite } cordierite, spinel, diaspore.

{ anthophyllite, cummingtonite } cordierite, plagioclase
passing by decrease of SiO_2 into
{ anthophyllite, cummingtonite } cordierite, plagioclase, spinel, diaspore.

{ anthophyllite, cummingtonite } plagioclase
passing by decrease of SiO_2 into
{ anthophyllite, cummingtonite } plagioclase, spinel, diaspore.

The varying hypotheses noted above can now be considered in the light of these facts. The view that they represent sediments abnormally rich in chloritic material can scarcely be logically entertained, considering their intimate association with the greenstones, the gradations they exhibit, and the presence among them of much plagioclase. The absence of such mineralogical assemblages from among the bands of sediments points further to the unlikelihood of this hypothesis. Extensive metasomatic changes in sediments or siliceous leptites, involving large-scale introductions of magnesia and iron oxides from an adjacent igneous intrusion, have been claimed by Eskola for the somewhat similar anthophyllite-cordierite rocks of the Orijärvi area. The cummingtonite-plagioclase rocks of that area have been described as metasomatized amphibolites which are abundant in the field. Without entering into, or discussing, the evidence given by Eskola for the rocks of the Orijärvi field, we may state that the evidence for metasomatic processes of this nature is wholly wanting at Kenidjack. Apart from the inherent difficulty in believing such magnesia-rich solutions are available in the residual liquids of granitic magma, it is seen that the normal sediments at the immediate contact with the granite have suffered no metasomatism of this nature, anthophyllite-cordierite rocks being developed distant from the contact. The chief pneumatolytic effects observable in the sediments are the introduction of water,

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boron, fluorine and lithium, revealed in tourmaline, fluorspar (not common) and white mica in the sediments, and tourmaline and axinite in the greenstones.

The fact that one of the analyses (that of the anthophyllite-cordierite hornfels) is closely comparable with that of a contaminated basic rock—a cordierite norite from Huntly, Aberdeenshire, leads one to consider the possibility that the anthophyllite and cummingtonite rocks owe their peculiarity in composition to contamination of the dolerites by aluminous sediments. There is, however, no suggestion from field or microscopic study which would lend support to this belief. The junctions between sediment and greenstones are sharp except in so far that some commingling has been effected by the intense shearing which the whole complex has suffered prior to contact metamorphism, nor do we find evidence of cores of hornfelsed sediments passing out through anthophyllite-rich rocks into the normal greenstones such as might be expected on this hypothesis.

There remains the fourth hypothesis which we believe to be responsible for the nature and relationships of these peculiar rocks. Briefly it is considered that the original doleritic intrusions were subject in part to intense atmospheric weathering whereby calcite, chlorite, serpentine and iron oxides were developed from the plagioclase, pyroxene and possibly olivine. The formation of calcite from basic plagioclase resulted in the freeing of alumina possibly as bauxite or other hydrous oxide. As a result of these processes, and the ready migration of lime and alkalis (soda), the dolerites were largely leached of these constituents. The whole was then subjected to intense shearing whereby the lime-rich areas gave rise on contact metamorphism to hornblende, and the chlorite and aluminous residues gave rise to the cordierite-anthophyllite rocks. A cordierite-anthophyllite rock would represent the extreme stage of leaching, but intermediate stages would be represented by those transition rocks in which plagioclase is present in significant proportions.

It is in harmony with this view that we find the anthophyllite and cummingtonite rocks essentially in intimate association with the greenstones, and further that transitions are met with between anthophyllite-cordierite assemblages and cummingtonite-plagioclase rocks with varying percentages of felspar, representing varying stages of leaching. The latter types are the most intimately associated with recognizable greenstones. Greenstones composed of green hornblende and plagioclase are found to contain areas of anthophyllite and plagioclase, or cummingtonite and plagioclase. A greenstone hornfels containing areas of diaspore and spinel has also been described (p. 29 and Plate II, Fig. 5).

Many of the greenstone bands consist essentially of green hornblende with minor plagioclase, and veins of green hornblende are sometimes seen crossing the cummingtonite hornfelses. At the other extreme, veins of cummingtonite are seen frequently cutting the cummingtonite and anthophyllite hornfelses and may extend across bands

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of greenstone. The field exposures bear witness to the extensive crushing and shearing the rocks have experienced. The cummingtonite veins doubtless represent serpentinous veins in the thoroughly altered greenstones. Evidence of the migration of lime among the greenstones is not wanting, and is seen, not only in the peculiar composition of some of the undoubted greenstones (their richness in hornblende), but also in the occurrence of veins of green hornblende, and in the abundance of axinite and lime garnet in the form of veins and large masses. At the Crowns, a mass of axinite-rich rocks is cut by a large vein or dyke composed largely of lime garnet, the vein itself reaching a width of a foot or more. The anthophyllite and cummingtonite rocks are therefore regarded essentially as greenstones which have been extensively decomposed and subsequently sheared with loss of lime (probably as calcite) and soda (possibly as albite).

That such a process affecting rocks of normal doleritic composition could yield rocks of the bulk composition of the anthophyllite and cummingtonite rocks is clearly seen from an examination of the plot of analyses in Fig. 4 already referred to. The points 10, 9, 8, represent the analyses of an average of 50 plateau basalt lavas and a hornblende schist of doleritic origin (point 10), and two Newlyn greenstones (points 9 and 8). It is clearly seen that analyses 1, 2, 3, lie along lines extending from the CaO apex through the field of the basic igneous rocks of which the position of 10 in the plot may be taken as centre. The analyses indicate, however, that besides CaO an abstraction of soda is also indicated. In the plot, soda is eliminated with an equivalent proportion of alumina (as in albite) and it is not unreasonable to believe that soda was removed as such from the greenstones. The presence of spinel and diaspore in these rocks is clearly dependent on the available silica. Among the cummingtonite types quartzose bands are frequently met with. The richness in quartz of these bands is clearly due to silicification in the form of strings and veins. Some bands of anthophyllite rock are comparatively rich in biotite. Although the greenstones themselves often contain significant percentages of biotite in their hornfelsed condition, it is more than probable that some of the anthophyllite rocks have been enriched in potash by migration of potash-containing solutions. It appears to be purely a local enrichment such as is commonly met with among altered rocks.

The textures of the anthophyllite-cummingtonite rocks are closely similar to those of the metamorphosed greenstones. The presence of streams of ilmenite grains and laths arranged parallel to the original foliation, or winding around cores of amphibole, which is a characteristic feature of both the anthophyllite-cummingtonite rocks and those rich in cordierite, finds its parallel among the greenstones proper which show characteristically green hornblende with a similar disposition of ilmenite streams. In the true sedimentary hornfelses, such ilmenite streams appear to be altogether absent.

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PLATE I

HORNFELSES FROM KENIDJACK, CORNWALL

Magnification 30 diameters

Fig. 1. Anthophyllite-cordierite hornfels, Kenidjack Castle; showing tufts of anthophyllite set in a base largely of quartz and cordierite.

Fig. 2. Anthophyllite-biotite-cordierite hornfels, cliffs north of Kenidjack; showing idioblastic crystals of anthophyllite set in a ground of brown biotite. Streams of ilmenite.

Fig. 3. Anthophyllite - plagioclase - spinel hornfels, Kenidjack Quarry. Pleonaste enclosing idioblastic diaspore in a ground of anthophyllite, cummingtonite and plagioclase. Parallel streams of ilmenite granules proceed through the pleonaste. E. 13452.

Fig. 4. Anthophyllite-cordierite-spinel-diaspore hornfels, Kenidjack Quarry; showing clusters of pleonaste and diaspore associated with coarsely grained cordierite and anthophyllite.

Fig. 5. Anthophyllite-spinel-chlorite-diaspore hornfels, Kenidjack Quarry; showing large pleonaste grains enwrapping diaspore associated with anthophyllite and clinochlore (pneumatolytically developed from cordierite).

Fig. 6. Anthophyllite-cordierite hornfels, roadside, Kenidjack Quarry. A coarse-grained type. Curved prisms of anthophyllite set in cordierite. The orientation of the streams of ilmenite passing through both minerals is that of the ilmenite in the greenstone from which the rock is derived.

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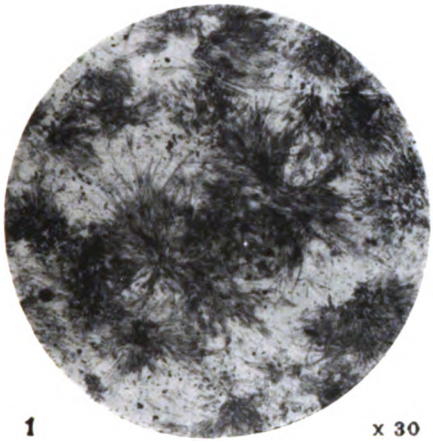

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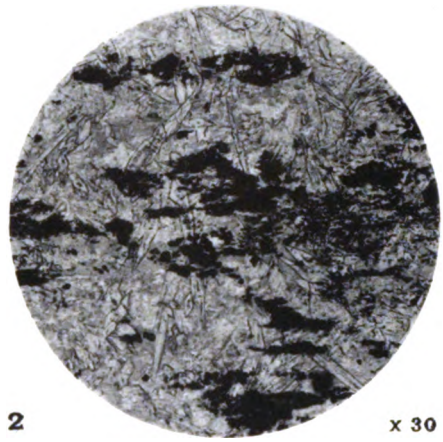

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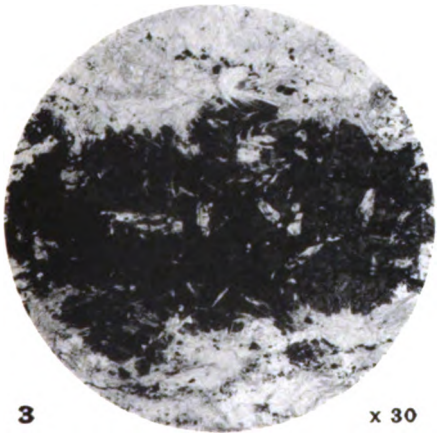

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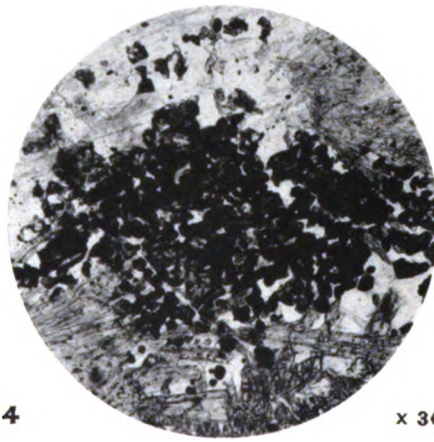

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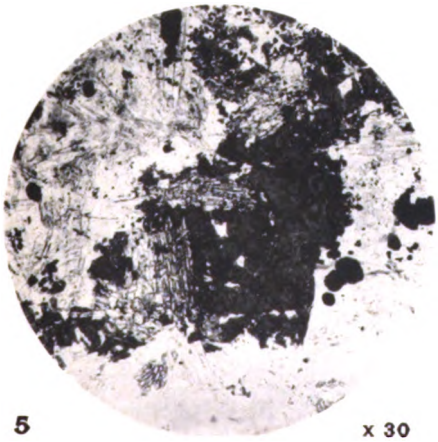

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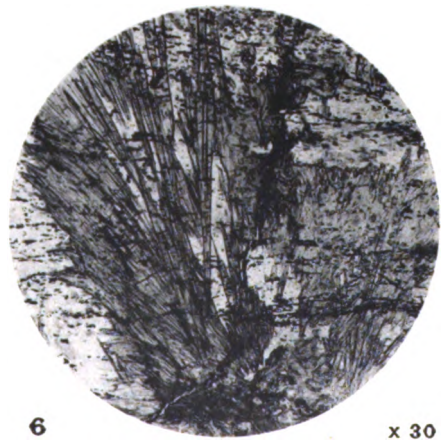

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KENIDJACK HORNFELSES

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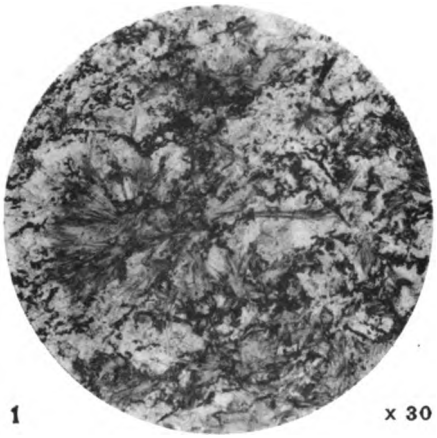
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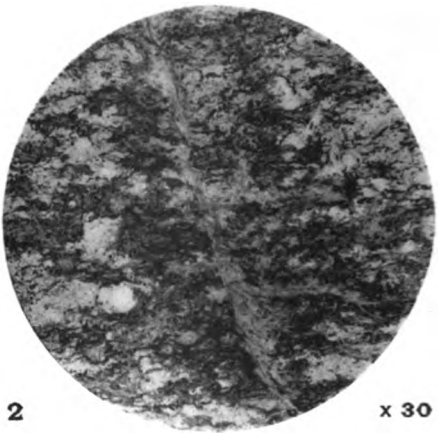
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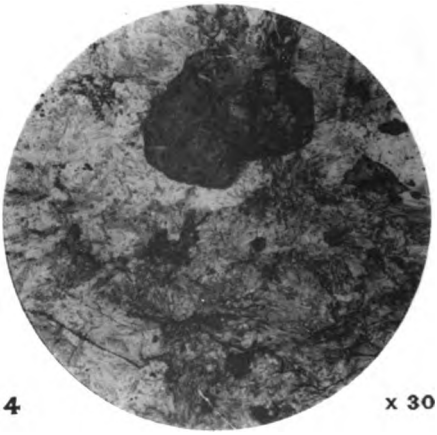
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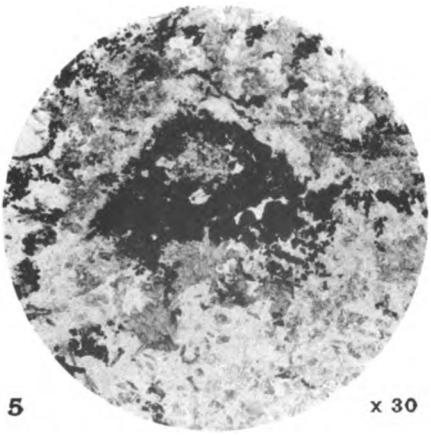
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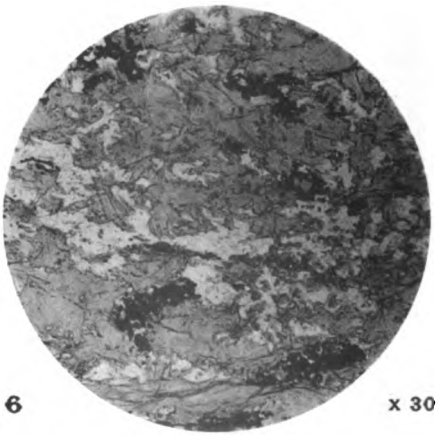
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KENIDJACK HORNFELSES

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PLATE II

HORNFELSES FROM KENIDJACK, CORNWALL

Magnification 30 diameters

Fig. 1. Cummingtonite-cordierite hornfels, Kenidjack Castle; showing tufted cummingtonite with anthophyllite in a base of clear cordierite.

Fig. 2. Cummingtonite-plagioclase-quartz rock with vein of cummingtonite, Kenidjack Castle.

Fig. 3. Cummingtonite-biotite hornfels, extremity of Kenidjack Point; showing nests of cummingtonite with some biotite in a base of biotite, quartz, plagioclase and ilmenite.

Fig. 4. Tourmaline-chlorite hornfels, Kenidjack Quarry; a pneumatolytically altered hornfels showing anthophyllite, cummingtonite, tourmaline and clinochlore, the latter developed from cordierite.

Fig. 5. Dolerite hornfels, Kenidjack Quarry; showing spinel with enclosed diaspore in a ground of plagioclase, and green hornblende with clinochlore. E. 13460.

Fig. 6. Dolerite hornfels, North Zawn Quarry. A typical hornfelsed greenstone composed of green hornblende, finely granular plagioclase and streams of ilmenite granules. In parts of this slice pleonaste is developing.

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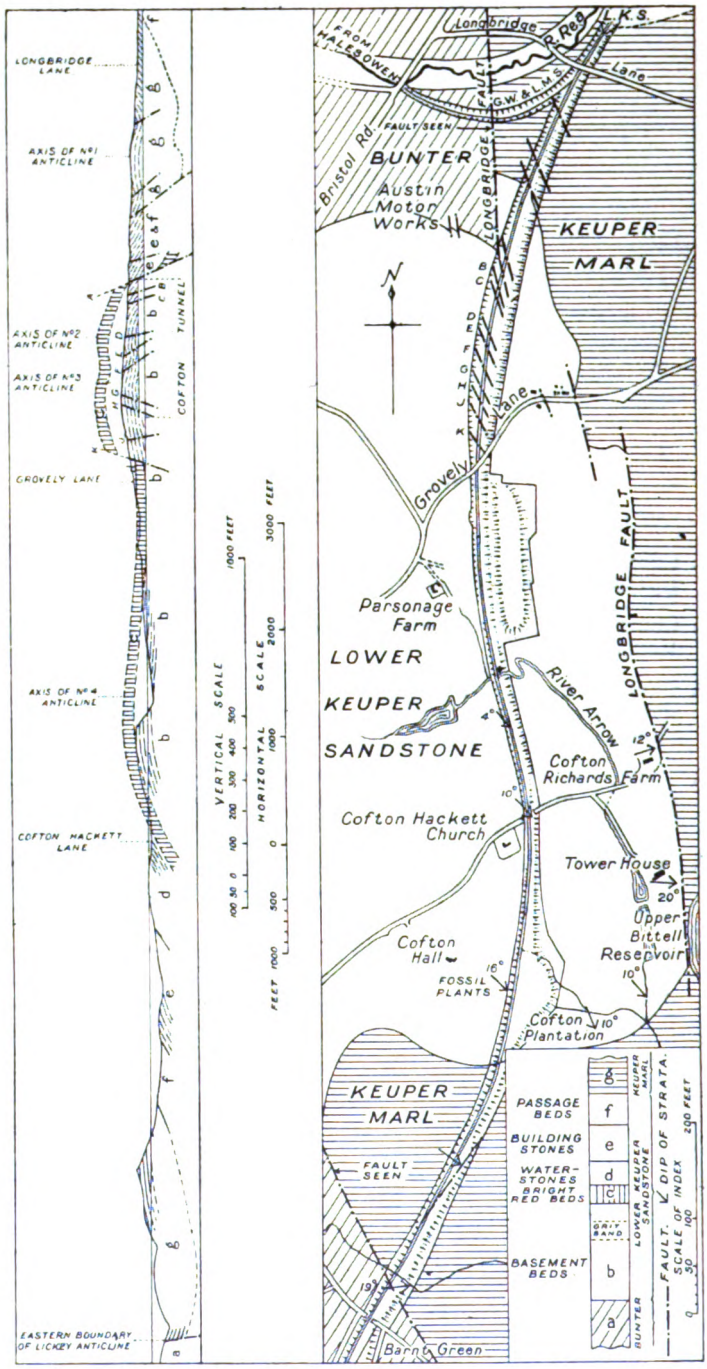

FIG. 1.—*Geological map and horizontal section of the Longbridge and Barnt Green Widening.*

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III.—THE L. M. & S. R. LONGBRIDGE AND BARNT GREEN WIDENING NEAR BIRMINGHAM

BY

T. ROBERTSON, B.Sc.ENG., PH.D., A.INST.M.M., AND
R. T. MCCALLUM, O.B.E., B.Sc., B.Sc.ENG., M.INST.C.E.

Text-figures 1 and 2

Plate III

INTRODUCTION

Certain interesting exposures in the Keuper Series have recently been made, during the widening of the L. M. & S. R. Derby and Bristol Line between Longbridge and Barnt Green, about 6 to 9 miles south of Birmingham. The excavations have thrown considerable light on the Lower Keuper succession and structure in this area, on the behaviour of the Longbridge Fault, and on the nature of engineering difficulties that may be expected in similar circumstances. The drift covering was insignificant and showed nothing of interest.

The length of line concerned formed part of the old Gloucester and Birmingham Railway, built in 1838-41; and the widening was undertaken between 1926 and 1929 to provide two additional lines on the east side of the existing lines.

THE LOWER KEUPER SANDSTONE OF THE BROMSGROVE AND BIRMINGHAM DISTRICTS

The following general section in the Bromsgrove district is based on unpublished work by Dr. W. Gibson and on a paper by Dr. L. J. Wills[1] on the Lower Keuper rocks of Worcestershire:—

	Ft.
Keuper Marl:—Red marls with some thin flaggy fine-grained white sandstones (skerries) with pseudomorphs of salt crystals	600
Lower Keuper Sandstone:—	
Sandstones, thin, flaggy, rather coarse-grained, brown, white and red, with a line of erosion at the base in some places. No pseudomorphs or plant-remains	30
Thick-bedded red sandstones. No fossils. Marl bands thin and rare	40
White and greyish-white sandstones, highly current-bedded. Traces of copper, lead and manganese. Numerous plant and fish remains. Contains bands of greenish marl, often up to 6 ft. thick. In some places highly calcareous	30
Sandstone, thick-bedded, highly micaceous, chocolate-red	20
Fine-grained, bright red, soft sandstones	15
Sandstones, coarse, highly current-bedded, red. Bands of marl up to 15 ft. in thickness not uncommon. Sandstones thick-bedded, but generally incoherent. No fossils or accessory minerals. Two or more hard calcareous bands, one of them about 30 to 40 ft. above the base	100
Upper Mottled Sandstone	—
Total thickness of Lower Keuper Sandstone	235

[1] *Proc. Geol. Assoc.*, vol. xxi, 1910, p. 249.

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The base of the Keuper may be either a conglomerate, as at Tutnall and Cobley; flaggy and marly and resting evenly on the Upper Mottled Sandstone, as at Vigo Bridge; or it may consist of sandy beds passing gradually into Upper Mottled Sandstone, as at Mount Segg.

When the Birmingham district was re-surveyed on the six-inch scale it was not found possible to subdivide the Lower Keuper Sandstone succession.[1] It is estimated to average some 300 to 350 ft. in thickness and consists chiefly of sandstone which varies from red and brown to white or buff, the paler shades being more characteristic of the higher beds, which are also finer in grain.

With the exception of small fragments of quartz, pebbles are usually absent. Current-bedding is sometimes very pronounced. The sandstone is parted by bands of red marl. It is thus seen that the well-marked divisions of the Bromsgrove area become vague and indefinite to the north.

As the Upper Mottled Sandstone approaches the line of the Birmingham Fault from the west it either changes its facies or is overlapped, and there is no satisfactory means of distinguishing between the Keuper and Pebble Beds sandstones.

THE KEUPER SUCCESSION BETWEEN LONGBRIDGE AND BARNT GREEN

The development of the Keuper Sandstone between Longbridge and Barnt Green is shown in the following generalized table (see also Fig. 1, p. 42):—

	Approximate estimated thickness in ft.	Localities.
(*g*) Keuper Marl: chocolate marls with skerries	lowest 200	Cutting N. of Barnt Green and N. end of Cofton Tunnel cutting.
(*f*) Alternating bands of marl and fine-grained sandstone (Passage beds)	30	Longbridge Lane and N. end of Cofton Tunnel.
(*e*) Sandstones, red, brown, buff, grey-green, and grey-blue, with plant-remains and bands of greenish marl (Building stones)	40	North end of Cofton Tunnel and Cofton Hall Farm.
(*d*) Micaceous sandstones and marls (Waterstones)	25	Cofton Hackett Lane Bridge.
(*c*) Soft red sandstone, resembling Upper Mottled Sandstone in appearance (Bright Red beds)	20	Cofton Tunnel cutting at Grovely Lane Bridge, and cutting N. of Cofton Hackett Church.
(*b*) Coarse incoherent sandstones with beds of marl and calcareous conglomerate (Basement beds)	100	Cofton Tunnel cutting and cutting N. of Cofton Hackett Church.
(*a*) Upper Mottled Sandstone	probably over 50	Austin Motor Works near N. end of Tunnel.

[1] Eastwood, T., in 'The Country around Birmingham' (*Mem. Geol. Surv.*), 1925, p. 81.

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Approximate total thickness of Lower Keuper Sandstone, 215 ft.[1]

(*a*) The base of the Keuper Sandstone was exposed in 1927 in excavations for new buildings at the Austin Motor Works, just north-west of the north end of the tunnel. A brownish sandstone, somewhat pebbly and incoherent, was seen overlying a bright brownish-red sandstone of Upper Mottled Sandstone type. The exposure showed minor faulting. The slope northwards is underlain by similar red sandstone, whilst Bunter Pebble Beds are exposed on the opposite bank of the River Rea. This indicates the presence of a distinct Upper Mottled Sandstone facies at Longbridge. Though these red sandstones were observed in one or two places during the six-inch survey, it was not considered advisable to subdivide the Bunter here owing to scantiness of evidence.

(*b*) This group is well exposed in the tunnel-cutting along the site of the tunnel, where it consists chiefly of fine-grained brownish sandstones, mainly incoherent, with beds up to 4 ft. thick of chocolate marl and lenses of calcareous marl conglomerate (Fig. 2).

The rocks in this exposure, however, are so much broken by faulting that little can be said regarding the relative disposition of the various types; but the sandstones in the lower part of the group, as displayed south of the fault F, are more calcareous, and therefore harder, than those north of this fault. The calcareous content is either in the form of a cement throughout the sandstone or of calcareous concretions which weather out on exposed surfaces.

In the upper part of the group, as shown north of the fault F, the sandstones are usually more or less marly and without pebbles, changing insensibly laterally into marls.

Above the south end of the tunnel are other sandstones, undoubtedly in the lower half of the group, and probably high in that half. They contain cavities, occasionally lined with calcite crystals. These cavities correspond to the calcareous concretions, and it

[1] Since this account was written a borehole has been put down at Longbridge Laundry, three quarters of a mile north-north-east of the railway junction at Longbridge (Fig. 1). This passed through the whole of the Lower Keuper Sandstone, and the cores confirm in all essentials the succession worked out in the widening. It was found, however, that groups (*c*) and (*d*) are rather more indefinite in the boring than in the widening, indicating a nearer approach to the rather vague sequence in the Birmingham area. Again, the sandstones of group (*b*) are almost non-pebbly, but there are some well-defined bands of calcareous marl conglomerate, especially towards the base.

The estimated thicknesses of the various groups in the borehole are as follows :— (*f*) 35 ft., (*e*) ? 60 ft., (*d*) 30 ft., (*c*) ? 20 ft., (*b*) 130 ft. This gives a total of 275 ft. for the thickness of the Lower Keuper Sandstone at this point, as against an estimated thickness of 215 ft. in the widening. The difference may be due to conservative estimates made in the faulted ground of the cutting, and to the adoption in our succession of the thickness at Bromsgrove for group (*b*), in default of absolutely definite local information. It is quite likely, however, that the Lower Keuper Sandstone, especially its lower portion, may thin out somewhat towards the pre-Triassic Lickey ridge. In any case the limits indicated are not beyond the normal rate of variation of the Keuper in other places. It is therefore thought best to leave the thicknesses in the widening as estimated in the field, especially as they were mostly worked out at least a mile and a half from the position of the boring.

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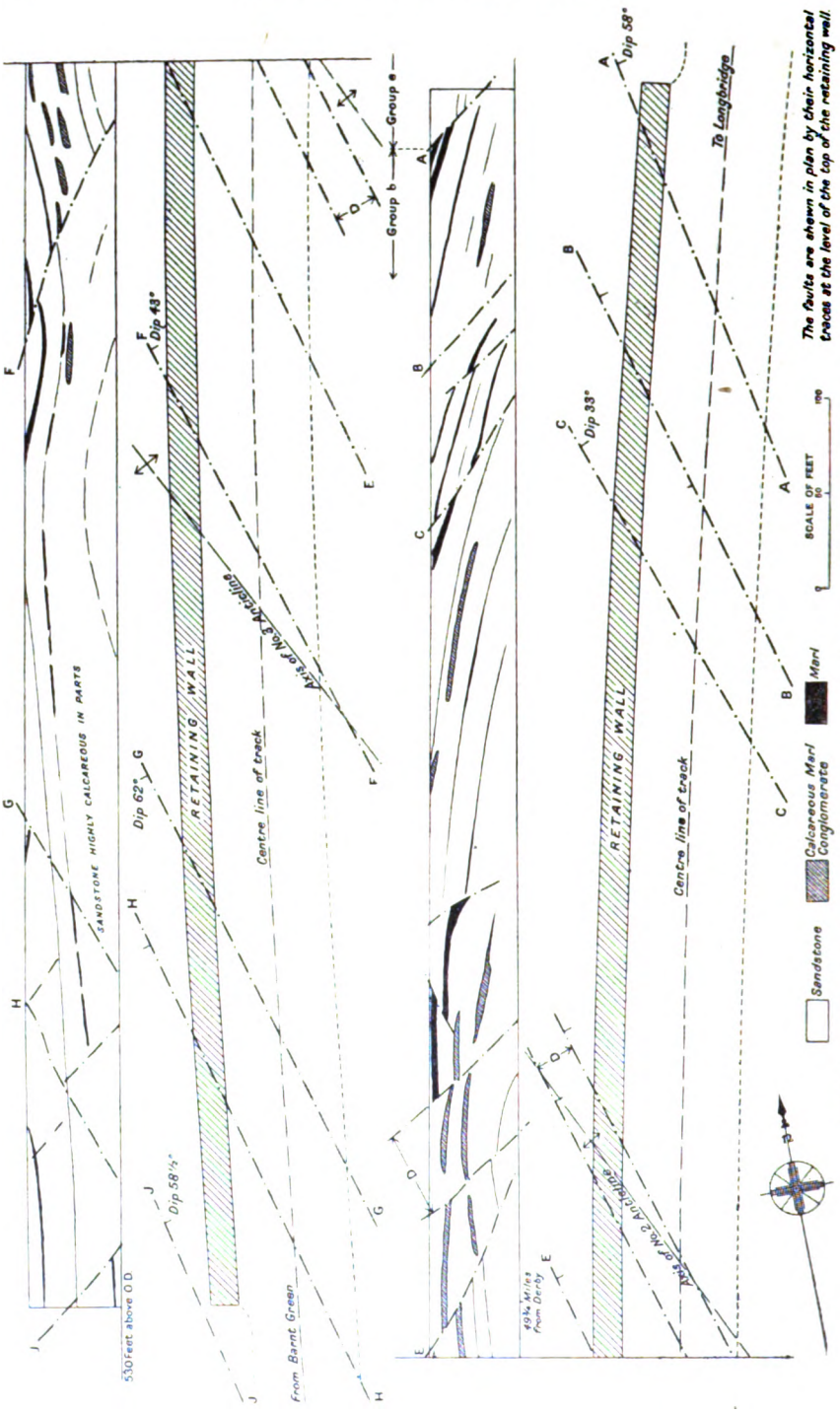

FIG. 2.—*Plan of Cofton Tunnel Cutting, and section behind the retaining wall.*

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would appear that they have been formed by the leaching out of the lime, especially as most of the cavities contain a little loose sand.

At an indeterminable but high horizon in the group is a somewhat remarkable bed of light brown current-bedded sandstone, coarse and gritty in parts, with layers of pebbles and having a thickness of some 20 ft. In the cutting this bed seems to be repeated three, if not four, times by faulting, and where it has been much broken some of the joints contain limonite. Possibly the very pale colour of this sandstone has some relationship to the mineralization of its joints.

Lenses of calcareous marl conglomerate occur throughout the group but are more common in the lower half. They contain pellets of indurated red marl, quartz, quartzite, etc., and are usually very hard. Associated with these are lenses of dark brown sand, almost black in places, with marl pellets and occasional pebbles. They are possibly decalcified calcareous marl conglomerate.

A portion of the same group free from faulting is exposed in the small cutting north of Cofton Hackett Church. Here some 35 to 40 ft. of sandstone with partings of marl and calcareous marl conglomerate are seen. They appear to constitute the highest part of the group as they are overlain by the succeeding group (*c*). Calcareous concretions are common in some bands of the sandstone, and there are sporadic pebbles in parts.

(*c*) Certain beds in the tunnel cutting, south of the fault K that runs obliquely across the cutting just north of Grovely Lane, may belong to the second lowest group in the Bromsgrove sequence. They are light reddish-brown in colour, brighter than any other beds in the series, and are exposed to a thickness of some 15 ft., the upper portion being obscured. They lie on brown sandstone with calcareous concretions and contain two or more thin beds of calcareous conglomerate with marl pellets and millet-seed grains of sand. There is, however, no calcareous conglomerate recorded at this position in the Bromsgrove sequence.

Similar bright red sandstone, but without calcareous conglomerate, appears in the lane east of the Grovely Lane Bridge, on the opposite side of a fault zone. It is some 70 ft. higher than the exposure in the cutting, but is thought on lithological evidence to be the same band.

The south end of the cutting near Cofton Hackett Church (Fig. 1) shows similar reddish sandstone, also without calcareous conglomerate, overlying the beds of group (*b*). This sandstone is exposed to a thickness of over 8 ft. and from its position in the sequence it probably belongs to group (*c*).

(*d*) Excavations for the bridge foundations just north-east of Cofton Hackett Church showed over 15 ft. of alternating beds of dark brownish-red sandstone and chocolate marl, micaceous and thin-bedded. These are apparently a short distance below the

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position of the building stones (*e*). The corresponding beds at Bromsgrove are described as thick-bedded sandstones, highly micaceous and chocolate-red in colour.

(*e*) This group is very distinctive in character. It consists mainly of soft sandstones, fine-grained, current-bedded and micaceous. They become more marly in the higher part of the group. Their colour varies from reddish-brown, pale brown and buff in the upper part to blue-grey and green with thin beds of greenish marl in the lower part. They also contain lenses of calcareous conglomerate, with pellets of either green or chocolate marl.

The beds of this group were found at the north end of the tunnel, immediately north of the main eastern component (A) of the Longbridge Fault ;, also in a deep drain on the west side of the railway east of Cofton Hall, and in culvert foundations and a shallow stream diversion on the opposite side of the railway in the same area.

The exposure at the tunnel was unfortunately much broken and dislocated by faulting, but displayed a remarkable variety of colours in the sandstones. The buff and brown tinted sandstones have, to a remarkable degree, the property of hardening on their surfaces when exposed to weather. They were used as ashlar in the tunnel faces at the time of construction, and after 90 years their arrises are as sharp as when first tooled. The blue and green tinted sandstones, and some of the greenish marls, yielded many fragmentary plant-remains. No fossils were found in the brown and buff sandstones.

Dr. Wills contributes the following notes on the fossils from these beds :—" The only fossils so far obtained [in this area] come from the grey beds near the northern entrance of the old tunnel. They include the following plants :— Pith cast of *Schizoneura ?*, pith casts of coniferous stems, possibly *Voltzia*, leaf of *Yuccites vogesiacus* Sch. & Moug. These are all in sandstone. There is indeterminate plant debris in some of the greenish shale lenses.

" A few fragments of the scorpion, *Mesophonus*, were found in some green shale that occurred near the top of the cutting, near the north face of the tunnel . . . . The species is indeterminate.

" The flora and fauna, as far as they go, agree precisely with those from the fossiliferous uppermost portion of the Keuper Sandstone as developed at Bromsgrove. The general lithological facies is also very similar.

" One of the coniferous casts is quite good and comparable with my Pl. 17, figs. 2 and 5[1]—put there as of uncertain affinities. Others are slightly different and perhaps represent different states of preservation of the same type of wood."

In the drain exposure near Cofton Hall similar sandstones with better preserved fossil plants were found, and also thin beds of

[1] *Proc. Geol. Assoc.*, vol. xxi, 1910.

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calcareous conglomerate with pebbles of green marl. The shallow exposure in the stream diversion showed green copper staining and also very poor fossil plants. The sandstones become more marly and assume darker reddish-brown colours towards the top of the group, passing more or less insensibly into group (*f*).

East of the railway similar grey sandstones, though rather thicker bedded than in the railway exposures, can be seen at Cofton Richards Farm and at the Tower House, on the west side of Upper Bittell Reservoir, on the southward extension of the Longbridge Fault.

(*f*) The transition beds to the Keuper Marl were well exposed at the Longbridge end of the widening passing conformably up into the Marl and also, though to some extent limited by the faulting, immediately north of the tunnel. They correspond in character to the beds in this part of the succession at Bromsgrove, being composed of brown, buff and green flaggy sandstones with marl bands, the marls becoming predominant towards the top.

A small exposure of these transition beds is seen just inside Cofton Plantation, on the east side of the railway, south-east of Cofton Hall. This requires an alteration to the boundary between the Lower Keuper Sandstone and Keuper Marl, as shown on the one-inch Old Series map, between Kendal End and Upper Bittell Reservoir.

(*g*) The base of the Keuper Marl is exposed in the cutting just north of Longbridge Lane. As elsewhere in the district there is a gradual change from sandstone with marl bands to marl with sandstone bands, the line being drawn at the top of the highest persistent sandstone. This exposure necessitates an alteration of the boundary drawn on the published maps (one-inch 168 and six-inch Worc. 10 S.W.) as there was no satisfactory evidence of its position available during the survey.

The exposure of Keuper Marl between Longbridge Lane and the north end of the tunnel is of the usual type, with skerries containing pseudomorphs after rock-salt. The cutting just north of Barnt Green Station shows slightly faulted beds rather higher in the sequence than those at Longbridge, containing skerries with pseudomorphs and a few very thin veins of gypsum.

THE STRUCTURE OF THE LONGBRIDGE AND BARNT GREEN AREA

The beds described above are disposed in a series of folds coursing N.N.W.-S.S.E. and pitching at a low angle to the S.S.E. The pitch, however, is too low to be appreciable within the extent of the excavations. There are four anticlinal axes in the Keuper as exposed along the widening, roughly parallel and apparently subsidiary to the main Lickey anticline, which lies immediately to the west and is almost touched by the southern end of the widening. These axes are numbered 1 to 4 in the following description, and the principal faults are indicated by letters A to K both here and in

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Figs. 1 and 2. Anticlinal axes 2 and 3 might with justice be looked upon as one double-crested anticline comparable in size with 4, and axis 1 might be considered as a roll along the axis of a larger syncline; but it is simpler for descriptive purposes to consider them as distinct. The northern portion of the area was mapped on the six-inch scale by T. Eastwood, who located the surface position of the Longbridge Fault in the Austin Motor Works.[1] The recent excavations have confirmed most of his conclusions.

1. The excavations just north of Longbridge Lane show the western limb of a gentle anticline in the top beds of the Keuper Sandstone. There is practically no fracturing here and the syncline to the south shows Keuper Marl (*g*), evenly disposed for the most part. Some 300 yds. south of Longbridge Lane, in the Keuper Marl, the crest of a gentle anticline is cut by the east slope of the cutting. There are several normal faults on the eastern limb, whilst three reversed faults occur on the western limb. The dip and these few minor dislocations are brought out by greyish-green sandy bands (skerries) in the generally reddish-brown marl.

2. Some 200 yds. north of the north end of the tunnel the dip of the marl on the western limb of the syncline becomes much steeper and some of the transition beds (*f*) and building-stones (*e*) crop out, with several faults traversing them in a S.S.E. direction. Just south of the north face of the tunnel a fault (A) with a throw of about 80 ft. to the E.N.E. enters the cutting on the west side and traverses it obliquely, bringing in the upper middle sandstones of group (*b*). Thence to the south end of the tunnel all the excavation is in this group. The crest of the second anticline crosses the west side of the cutting 160 yds. from the north end of the tunnel and is much broken by faulting. It was on the northward continuation of this crest that the base of the Keuper was exposed in the Austin Motor Works, 100 yds. north-west of the north face of the tunnel. As the top of the Bunter is nowhere exposed in the cutting, this indicates a displacement of about 80 ft. in the broken ground just west of fault A. On the crest of this anticline, marked by a depression in the ground east of the railway, there is some tensile trough-faulting, but the main faults throw down to the east-north-east. The dip of the more important faults is shown in Fig. 2. Besides the faults coursing south-south-east there are innumerable cross-fractures and joints, showing that the ground has been much smashed.

3. The third anticline crosses the west face of the cutting about 190 yds. south of No. 2, and is similar to it in character, but not quite so much broken. Between No. 3 and Grovely Lane Bridge the sandstones are rolling slightly, as indicated by thin bands of interbedded marl.[2] These marl bands are often somewhat sheared, and it is very difficult to distinguish them from the layers of puddled marl lining the faults.

[1] 'The Country around Birmingham' (*Mem. Geol. Surv.*), 1925, pp. 85 and 102.
[2] Survey Photograph No. A. 2026.

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SLIP ON WESTERN SLOPE OF COFTON TUNNEL CUTTING.

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Some 70 yds. south of the south face of the tunnel a fault (K) crosses the west side of the cutting throwing the beds down to the south-west and brings in group (*c*) at the bottom of the cutting. Thence to the southern end of the section the beds rise gently to the south-west, with some rolling.

4. The rise just mentioned is the eastern limb of the next anticline, the axis of which passes up the valley south of the tunnel cutting. It is possible that there is some faulting along this axis, emphasizing the weakness that has made it a zone of erosion. The western limb is exposed in the cutting just north of Cofton Hackett Church, where pebbly sandstones and calcareous marl conglomerates of group (*b*) appear, overlain along the southern half of the cutting by the red sandstones of group (*c*).

Thence to near Barnt Green the general dip of the beds is south-eastward, bringing in successively the higher beds of the Keuper. Each of the sub-divisions (*d*), (*e*), (*f*) and (*g*) has been recognized between this and the Keuper Marl cutting to the south.

Beyond this the eastern boundary fault of the Lickey anticline crosses the line, 100 yds. north of the bridge under the railway at Barnt Green. In the foundations for a culvert just north of this point Keuper Marl was found dipping to the east-north-east at 19°. The fault brings in the Bunter Pebble Beds, and these occupy the ground, under some drift, to the south end of the widening, at Barnt Green Station.

ENGINEERING DIFFICULTIES ENCOUNTERED IN THE WIDENING

Some reference should be made to the difficulties encountered and overcome, during the excavation of the tunnel cutting. These were caused by actual and potential slips, due to the structure of the ground in which the tunnel lay, and to which the formidable retaining walls bear witness.

Unfortunately no record of the strata passed through in driving the tunnel in 1838-1841 had been preserved,[1] so that it was not until the recent excavation had proceeded for some months, and a sufficient exposure had been made, that it was possible to interpret the general outlines of the geological structure, and to make some estimate as to the probable extent of faulting still to be revealed.

This estimate, admittedly rough, but subsequently proved to be fairly accurate, combined with the fact that a serious slip had occurred on a fault plane (F) (Plate III) in the western slope, was a timely warning that drastic and costly measures were necessary to prevent serious developments.

During the ensuing operations, however, many slips occurred in the cutting in both the permanent and temporary slopes, and these were due to a variety of conditions. Three types of slip may be distinguished.

[1] A brief account of the geology of the Birmingham and Gloucester Railway is given by H. E. Strickland, *Trans. Geol. Soc.*, ser. 2, vol. vi, 1842, p. 553. He says nothing about the tunnel, however.

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(1) The slipping of a length of slope *en masse* on the hanging wall side of a slickensided fault plane where the dip of the fault is toward the cutting.

(2) The breaking away of material from the back of a fault, *i.e.*, on its footwall side, where the dip of the fault is into the cutting slope. In this type the slipping is due to the broken, and usually wet, condition of the strata caused by the faulting, though the extent of it is naturally influenced by the direction of the dip of the strata relative to the cutting.

(3) The slipping between trough faults of overlying material on bedding planes when these are inclined towards the cutting and are slickensided. Such slickensides have been caused by slight movements in the beds, relative to and across each other when adjusting themselves to the displacements due to the trough faulting, and were found to occur chiefly in the crowns of the anticlinal folds.

Of these three types, the first and third proved the most serious, and in one instance, where both types were combined, a slip some 110 yards in length developed.

The slickensides varied from a highly polished surface on indurated marl to a thin film of extraordinarily smooth and greasy clay, the latter being the more dangerous.

With so many varying factors at work, such as the nature and wetness of the slickensides, the dip of the beds and of the faults, and the presence, or otherwise, of cross fractures and joints, no satisfactory estimate could be made as to the probable length of cutting slope that would slip.

In cases of the first type, however, it was usually found that, if the slope of the cutting or some considerable portion of it was steeper than the plane of the fault, a slip occurred involving a length along the cutting a little more than that to the point of intersection of the fault plane with the toe of the slope.

It will be gathered from this brief account that the engineers were, at the outset of the recent operations, at a disadvantage in not having any record of the strata passed through when the tunnel was driven. It was, however, an advantage to have, in the earlier days of the works, an appreciation of the geological structure of the ground and of its possibilities of causing engineering difficulties, so that adequate measures could be taken in time.

Geological conditions similar to those described above no doubt obtain in other cuttings and have caused, and still are causing, similar slipping, and it may be that a recognition of these conditions will enable such measures to be taken as will effectively prevent further troubles.

SUMMARY AND CONCLUSIONS

1. The Lower Keuper and Upper Bunter succession in the Barnt Green and Longbridge area resembles that of Bromsgrove in character and thickness. It contrasts with the same portion of the sequence to the north-east, where it was impossible to distinguish

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satisfactory sub-divisions either in the Keuper Sandstone or in the underlying Bunter.

2. The abnormal development to the east of Birmingham (p. 44) appears to have a direct connexion with the line of the Birmingham Fault, implying the existence of a ridge, and possibly also of movement in Triassic times, along the zone now indicated by the fault. There is thus less reason to expect abnormality in the Triassic succession below the Keuper Marl of south-western Warwickshire than would appear from the Birmingham succession : though the Burford boring appears to indicate an eventual overlap of the Keuper Marl southwards.

3. The widening gives a section through the country immediately to the east of the Lickey ridge ; and shows it to consist of a number of minor folds associated with faults coursing S.S.E. from the south-east corner of the South Staffordshire block, and probably dying out southwards.

4. The Cofton Tunnel cutting showed clearly, in three dimensions, the stepping of a fault-zone obliquely across a line of folding. The structure thus produced is difficult to demonstrate on a small scale owing to the limitations imposed by the principle of similitude, and so is seldom seen in natural sections, which are usually too small and are seen only in two dimensions. The echelon structure produced by comparatively simple and weak stresses is a commonplace to the worker in mining areas ; but it is seldom displayed in surface work with sufficient clearness to make possible its complete expression on a geological map as distinct from a conjectural diagram.

5. The excavations illustrate very clearly the fact that the general compressive stress exerted upon a rock mass produces a shear stress parallel to the plane of greatest resistance in the rock ; and it is this that becomes the dominant factor in rock movement even of the simplest type. This shear stress is not necessarily entirely in a vertical direction, there being in general a distinct horizontal component of stress parallel to the line of fracture.

6. It is very desirable that a record of the strata found in engineering works, especially where these works are to be covered up, should be made and kept for future reference.

The authors tender their grateful thanks to Mr. Alexander Newlands, C.B.E., M.Inst.C.E., Chief Engineer, L.M. & S.R., for his kindness in permitting them to publish the information obtained during the progress of the works, and for the loan of plans, sections, and photographs from which the illustrations have been prepared. They are also indebted to Messrs. J. Dickson and F. B. Belton, of the Engineering Staff, L.M. & S.R., on the works, for valuable help in many directions ; and to Dr. L. J. Wills, whose knowledge of the Bromsgrove area was willingly placed at their service.

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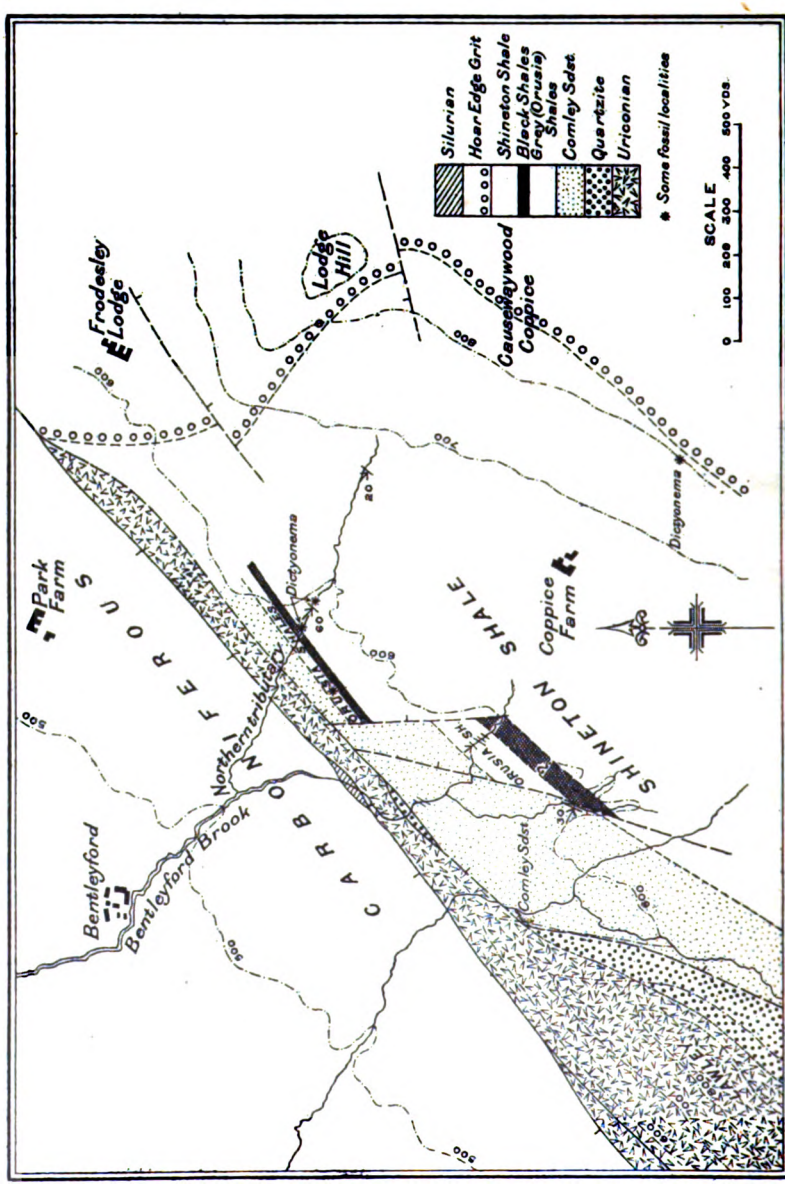

FIG. 1.—*Geological sketch map of the district south-east of Bentleyford, Shropshire.*

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IV.—A NEW UPPER CAMBRIAN SECTION IN SOUTH SHROPSHIRE

(ONE-INCH SHEET 152)

BY

C. J. STUBBLEFIELD, PH.D., A.R.C.Sc.

Text-figures 1 and 2

INTRODUCTION

Though Callaway as long ago as 1878[1] recognized Hollybush (or Comley) Sandstone and Shineton Shales in the valley between the Lawley–Caer Caradoc Pre-Cambrian ridge and Hoar Edge, the northern part of this valley has received scant attention geologically. In the south, Lapworth[2] and subsequently Cobbold,[3] by detailed research and excavation, have made classic the Lower and Middle Cambrian rocks of Comley; Cobbold also discovered in that neighbourhood an outcrop of Orusia Shales between the Middle Cambrian Sandstones and the Shineton Shales.

Watts[4] in 1925 stated that with two of his students he "found Comley Sandstone in streams N.E. of the Lawley"; the valley in which these streams flow is extensively covered by drift[5] and the Comley Sandstone exposures are few and, in general, apparently unfossiliferous. It seems therefore that without extensive excavation the subdivisions of this sandstone will remain unknown.

THE BROOK SECTION EAST-SOUTH-EAST OF BENTLEYFORD FARM

The most northerly tributary of Bentleyford Brook rises about a quarter of a mile below the Hoar Edge Grit escarpment and flows north-north-westwards across the Cambrian and Uriconian outcrops as an obsequent stream, joining the main Bentleyford Brook a few hundred yards north of the Lawley in the Coal Measure country beyond the Stretton Fault. Occasional exposures of Upper Cambrian shale, Comley Sandstone and Uriconian are seen in the streambed or in the banks, but the use of pick and shovel has uncovered (July, 1929) a fairly continuous Upper Cambrian succession in the

[1] Callaway, C., 'On the Quartzites of Shropshire,' *Quart. Journ. Geol. Soc.*, vol. xxxiv, 1878, pp. 759, 760.

[2] Lapworth, C., 'On the Discovery of the Olenellus Fauna in the Lower Cambrian Rocks of Britain,' *Geol. Mag.*, 1888, p. 484; and 'On *Olenellus callavei* and its Geological Relationships,' *ibid.*, 1891, p. 529.

[3] Cobbold, E. S., 1909-27; full references are given in 'The Stratigraphy and Geological Structure of the Cambrian Area of Comley (Shropshire),' *Quart. Journ. Geol. Soc.*, vol. lxxxiii for 1927 (1928), p. 552.

[4] Watts, W. W., 'The Geology of South Shropshire,' *Proc. Geol. Assoc.*, vol. xxxvi, 1925, p. 339. The sandstone was seen at two localities, respectively 550 yds. W. of Coppice House and 650 yds. N.W. of Coppice House.

[5] 'Summary of Progress' for 1928 (*Mem. Geol. Surv.*), 1929, pt. I, p. 59.

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stream-banks, 700-800 yds. east-south-east of Bentleyford Farm. The results have been plotted as Fig. 2.

The north bank was trenched downstream from the junction between the Upper Cambrian and the Comley Sandstone towards the Uriconian. The uppermost beds of the sandstone are thin-bedded glauconitic sandstones of a ' biscuit ' type, and in these, about

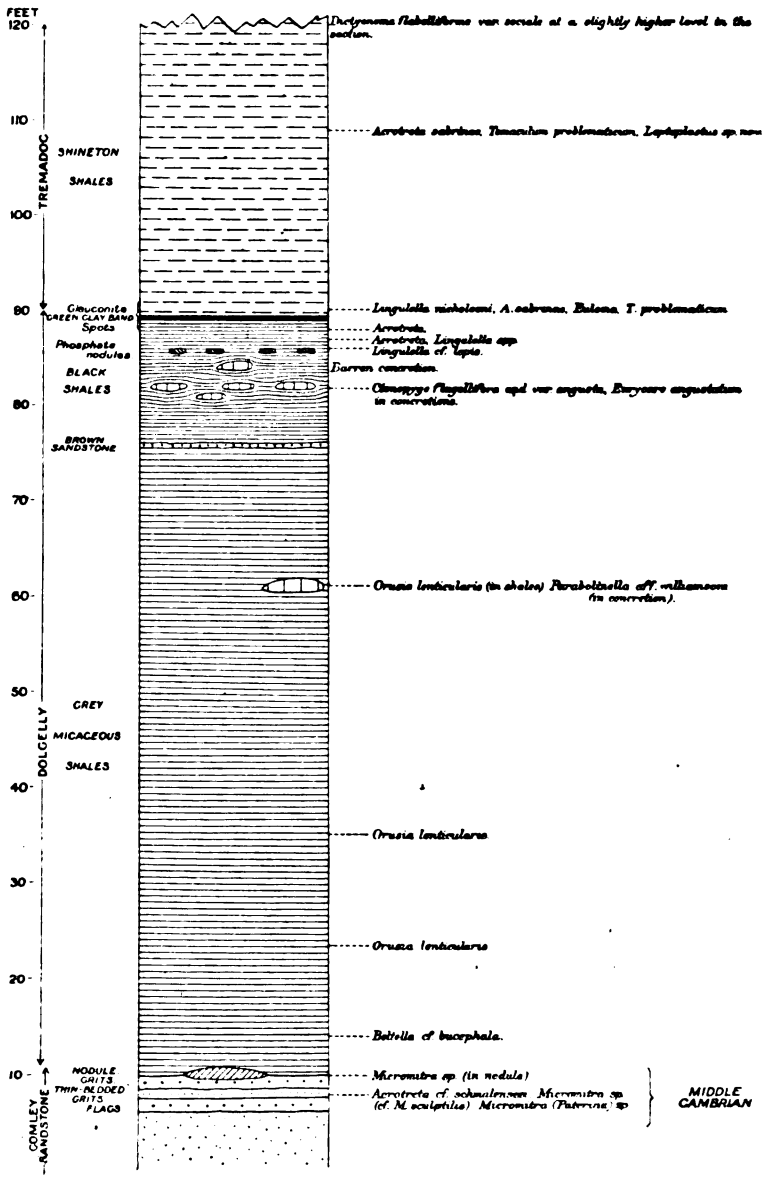

FIG. 2.—*The Sequence of Dolgelly Beds in north tributary of Bentleyford Brook.*

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1 ft. 8 in. from the junction, were found *Acrotreta* cf. *schmalenseei* Walcott [D. 2638],[1] *Micromitra sp.* of the group of *M. sculptilis* (Meek) [D. 2639] and *Micromitra* (*Paterina*) *sp.* [D. 2651], and the fauna indicates a fairly high horizon in the Middle Cambrian. Below this thin-bedded sandstone there occurs a glauconitic flaggy grit (lithologically similar to that seen in a stream 750 yds. to the south-east), but no further fossils have been found. Twelve feet down-stream from the Upper Cambrian junction the trenches failed to penetrate the drift cover, though trenching was continued to the Uriconian outcrop; perhaps the south bank would yield better evidence.

Phosphatic nodules occasionally showing spherulites of pyrite occur at the junction between the vertical grits of the Middle Cambrian and the very steeply dipping Grey or Orusia Shales of the Upper Cambrian (the Beds designated " Ca " in Cobbold's Comley Notation[2]). The nodules are probably of Middle Cambrian age, since one has yielded a single brachiopod fragment, *Micromitra ? sp.* [D. 2653-4].

The grey micaceous shales, about 63 ft. in thickness, strike obliquely across the stream at N.55°E., and a small *Beltella* cranidium [D. 2655-6] was collected 4 ft. from their base. Except for its small size, this trilobite closely resembles some specimens of *Beltella bucephala* (Belt) figured by Lake (' A Monograph of the British Cambrian Trilobites,' *Palaeont. Soc.*, pt. 5, 1919, pl. xii, figs. 13-14), and is identical with trilobite cranidia identified by the present writer as " *Beltella ?* sp. nov." from a septarian nodule in the Orusia Shales of Comley Brook, where it occurs associated with *Parabolina spinulosa* (Wahlenberg) and *Orusia lenticularis* (Wahl.).[3] The limestone-preserved specimens from Comley retain their shell and do not show the glabellar furrows such as are seen on shale-preserved specimens, from which the shell has been dissolved.

About 10 ft. higher in the shales, the brachiopod *Orusia lenticularis* (Wahl.) occurs in force and is found at intervals to within 13 ft. of the summit of the shales. At this level, a grey calcareous concretion[4] yielded *Lingulella sp.* and *Parabolinella* aff. *williamsoni* (Belt). The *Parabolinella* differs notably from *P. williamsoni* in its shorter pre-glabellar field and its narrower palpebral lobes.

A one-inch band of brown fine-grained sandstone separates the Grey Orusia Shales from the Black Shales. These are practically vertical and have a thickness of about 13 ft., while they appear to the naked eye as mica-free. Like the Black Band of Dolgelly, they are coloured sooty black and have a black streak. Their strike varies

[1] Dr. E. S. Cobbold, who has kindly confirmed these Comley Sandstone identifications, notes that *A. schmalenseei*, var. *matleyensis* Cobbold from the higher Middle Cambrian horizons of Comley has a more convex anterior slope in the ' lateral outline ' of the ventral valve, while the Bentleyford specimen has a nearly straight slope, agreeing more with Walcott's figures.

[2] *Op. cit.*, 1927, pp. 564, 571.

[3] In E. S. Cobbold, *op. cit.*, 1927, p. 557.

[4] [D. 2657-D. 2665a].

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from N.87°E. to N.70°E. Seven feet from their base a number of black bituminous limestone concretions, riddled with calcite veins, are aligned along the bedding planes. These nodules are of the cone-in-cone type, but usually the outer shell of cone-in-cone has weathered to a brown spongy decalcified mass, leaving a black homogeneous finely crystalline limestone kernel, occasionally showing slight colour-banding in directions parallel to the bedding of the shale. At a blow from the hammer, the rock emits a bituminous smell and for this reason is known as stinkstone.

These concretions are not invariably fossiliferous and have here yielded only one faunal assemblage[1] which is, with the exception of the brachiopod *Obolus* (*Bröggeria*) *salteri* (Holl), entirely trilobitic, consisting of *Ctenopyge flagellifera* (Angelin) with its variety *angusta* Westergård, *Eurycare angustatum* Angelin and *Leptoplastus* cf. *stenotus* Angelin.

The material comprises isolated cranidia, free cheeks, fragments of pleurae, immature cranidia and pygidia (' transitory pygidia ').

Four feet above the main concretion-bearing horizon is a band of phosphate nodules (possibly indicating slow deposition), and six inches above this, small brachiopods [D. 2773-2807a] abound in the shale and are found through a vertical thickness of 2 ft.; these include *Lingulella* cf. *lepis* (Salter) and an *Acrotreta* of the group of *A. idahoensis* Walcott.

The junction between the Black Shales and the succeeding Shineton Shales is marked by a slight change in strike and by a layer of grey-green clay, about an inch thick. For approximately 18 in. on either side of this junction-clay the shales are spotted with grass-green glauconite specks, a feature that would suggest a pause in sedimentation.

The characteristic and ubiquitous Shineton Shale small brachiopod fauna, *Lingulella nicholsoni* Callaway and *Acrotreta sabrinae* (Call.), is found immediately the green clay junction-layer is passed, and the brachiopods are accompanied by the enigmatical *Tomaculum problematicum* Groom (which probably represents trilobite coprolites); associated with these was also found a fragment of a pleura of *Euloma monile* (Salter). About 19 ft. higher in the series a *Leptoplastus* cranidium [D. 2628-9] was met with, of a type such as is occasionally seen in the lower Shineton Shales of the type district, and in shales 20 yds. upstream, appears in abundance *Dictyonema flabelliforme* (Eichwald), var. *sociale* (Salter), of aspect and in lithology indistinguishable from material seen in the lowest Shineton Shales of the Wrekin District, 7¾ miles to the north-east.

Dictyonema is found at frequent intervals in the section for a distance of 60 yds. upstream, but changes of strike and dip, indicating minor folds and possibly faults, make estimation of true thickness impossible in the Shineton Shale outcrops.

[1] [D. 2667-2769].

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OTHER SECTIONS IN THE LAWLEY AREA

Very fossiliferous Orusia Shales are also seen in rabbit-warren debris, 150 yds. to the south-west of their exposure in the section described above, and again in the south banks of a stream 480 yds. to the south-south-west ; here they have been displaced to the south-east by faulting, and dip only at 40 degrees.

Orusia lenticularis is infrequent in this last section but occurs in the lowest rock there exposed and is succeeded by *Parabolina spinulosa* (Wahl.), var., represented by pygidia and free cheeks.[1]

The Black Shales have not been recognized elsewhere in Shropshire, but from the fauna of the black limestone-concretions it is clear that the loose stinkstones, discovered by R. W. Pocock[2] in Dryton Brook (Eaton Constantine, 6¼ miles to the north-east), on the line of the Church Stretton Fault, were derived from such shales as these. The faunas are identical and represent a passage between the Subzone of *Leptoplastus-Eurycare* and that of *Ctenopyge flagellifera*.[3]

The Shineton Shales, in the wood 380 yds. south-east of Coppice House at about 800 ft. O.D., and farther south in the Blackhurst-Chatwall Road at about 770 ft. O.D., have yielded *Dictyonema flabelliforme* (Eichw.) almost directly under the overlapping Hoar Edge Grit. With these facts and in the absence of proof to the contrary, it is inferred that the Shineton Shales exposed in the Lawley valley belong only to the Zone of *Dictyonema flabelliforme*, that is, they represent only the lowest division of the Tremadocian Series.

STRUCTURE OF THE AREA

The Church Stretton Fault traverses this area from south-west to north-east with its components, a westerly fault (the continuation of which is designated F_1 in the Comley district by E. S. Cobbold[4]), and on the east side of the Lawley ridge a reversed fault called the Lawley Fault by Lapworth and F_2 by Cobbold.[5]

Dr. Robertson has mapped Cambrian Quartzite on the eastern side of the Lawley as far northwards as the hillside due west of Coppice House. He also found, in the western bank of a lane 830 yds. N.82°W. of Coppice House, a 20 ft. section of vertical glauconitic Comley Sandstone (with traces of hard glauconitic grit at the southern end of the exposure) practically adjoining the Uriconian outcrop and apparently with no intervening quartzite. A thin wedge of shattered quartzite is, however, seen in the left bank of the main Bentleyford Brook (680 yds. north-west of Coppice

[1] [D. 2602-2609]. The *P. spinulosa* pygidia have only 3 axial rings, but the pleural portion of the shield shows in the first segment the *P. spinulosa* bend of the pleural furrow as opposed to that seen in *P. brevis* Westergård.

[2] 'Summary of Progress' for 1927 (*Mem. Geol. Surv.*), 1928, pt. I, p. 41.

[3] See Correlation Table, p. 61.

[4] *Op. cit.*, 1927, p. 565.

[5] *Loc. supra cit.*

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House) between exposures of Uriconian igneous rock and soft glauconitic Comley Sandstone. Towards the quartzite junction, the Comley Sandstone is almost vertical but with the strike disturbed, presumably owing to its proximity to the fault F_2. A red-grey limestone, a few inches in thickness, containing pyrite and veined with calcite, forms a bluff in the stream-bed 15 or 20 yds. from the quartzite junction and strikes anomalously N.50°W. On the right bank, 20 yds. farther upstream, where vertical red and green striped sandstone are exposed, the strike is N.25°E., which strike-direction is retained 370 yds. to the south in the hard glauconitic grit band (of lithology similar to the Middle Cambrian Grit band seen in the northern tributary of Bentleyford Brook, 750 yds. to the north-north-east).

From the situation of the three exposures of the Grey Orusia Shales, and from other considerations, it is inferred that this shale outcrop, north of the Lawley, has been displaced successively westwards by two oblique faults both throwing down to the east. One of these faults may conceivably be a continuation of the Hoar Edge Fault (F_3) seen at Shoot Rough to the south.[1]

The Upper Cambrian Shales, judging from the steepness of their dip on the western side of their outcrop, would appear to have been compressed against the harder and older rocks. In the northern tributary of Bentleyford Brook, 25-30 yds. east of the Black Shale-Shineton Shale junction, a local disturbance of the general north-easterly strike suggests minor folding or small scale faulting, otherwise the succession seen would appear to be unfaulted.

GENERAL CONSIDERATIONS AND CORRELATION

The Upper Cambrian section described above supplies evidence of strata presumably hidden by the fault between the Comley Sandstone and Shineton Shales in the Wrekin district, and possibly also by the fault in Shoot Rough Wood near Comley.

The accompanying table shows the sequence of zones in Sweden as defined by A. H. Westergård[2] and its correlation with Norwegian and British Upper Cambrian areas. The Norwegian succession closely resembles that of Sweden and T. Strand[3] has recently modernized the older classification of Brögger. In Britain, little detailed subdivision has been attempted since the work of T. Belt[4] in North Wales. There, where all the deposits are of much greater thickness than in Scandinavia, Belt subdivided the 'Lingula Flags' of the older writers into three groups, the Maentwrog, Ffestiniog and Dolgelly, which groups he divided in turn into lower and upper

[1] Cobbold, E. S., *loc. supra cit.*

[2] 'Sveriges Olenidskiffer,' *Sver. Geol. Undersök.*, Ser. Ca, No. 18, 1922.

[3] 'The Cambrian Beds of the Mjösen District in Norway,' *Norsk Geol. Tidsskrift*, vol. x, pt. 3-4, 1929, p. 308.

[4] Belt, T., 'On some new Trilobites from the Upper Cambrian Rocks of North Wales,' *Geol. Mag.*, 1867, p. 294; and 'On the "Lingula Flags" or "Ffestiniog Group" of the Dolgelly District,' *ibid.*, pp. 493, 536; also *ibid.*, 1868, p. 5.

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Correlation of Scandinavian and British Upper Cambrian Rocks.

	SWEDEN.	NORWAY.	SHROPSHIRE.	NUNEATON.	MALVERNS.	WALES.	WELSH STAGE NAMES.
	Dictyograptus Shale	2e (Brögger)	*Dictyonema flabelliforme*	*D. flabelliforme*	*D. flabelliforme*	*D. flabelliforme*	Lower Tremadoc
	6 *Acerocare, Cyclognathus* and *Parabolina*	2d γ (Brögger)	...	...	...	...	
Peltura Sphaerophthalmus and *Ctenopyge*	5d *Parabolina longicornis*	...	...	...	...	...	
	5c *Peltura scarabaeoides*		...	*Sphaerophthalmus alatus*	*Peltura scarabaeoides*	*Peltura scarabaeoides*	
	5b *P. scarabaeoides*, var. *acutidens* and *P. minor*	2d	...	...	*Agnostus trisectus*	*Agnostus trisectus*	Dolgelly
	5a *Ctenopyge flagellifera* and *Protopeltura praecursor*		*Ctenopyge flagellifera* and *Eurycare*	...	? *C. flagellifera*[2]	...	
	4 *Leptoplastus* and *Eurycare*	2c	Main part of Zone 4 not proved	...	...	? *Eurycare*	
	3 *Parabolina spinulosa* and *Orusia lenticularis*	2b	*P. spinulosa* and *O. lenticularis*	? Moor Wood Flags	*O.* cf. *lenticularis*[3]	*Parabolina spinulosa* and *O. lenticularis*	Ffestiniog
	2 *Olenus*	2a β	...	*Olenus truncatus*[1]	...	*Olenus spp.*	Maentwrog
	1 *Agnostus pisiformis*	2a α	...		...	?	

[1] Illing, V. C., *Geol. Mag.*, 1913, p. 452. [2] A. H. Westergård suggests that *C. fusiformis* Lake is probably a synonym of *C. flagellifera* (Angelin).
[3] A specimen occurs in the Mus. Pract. Geology, collected by R. Gibbs.

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divisions. The strata containing *Lingulella davisii* (McCoy) form only the upper part of Belt's Ffestiniog group, and the fossil is only with certainty known from Wales.

The Maentwrog group (the Olenus Zone) has been recognized both in Wales and at Nuneaton.

The Ffestiniog group apparently has no independent development in Scandinavia, but its position is inferred to lie between Zones 2 and 3 of Westergård's classification.

With the finding of the Ctenopyge-Eurycare horizon in Shropshire, all except the two topmost of the Swedish zones have now been recorded from the British Dolgelly Beds, and of these horizons, the Zone of *Parabolina spinulosa* and that of *Peltura scarabaeoides* also extend to New Brunswick.

The junction between the Middle and Upper Cambrian in the Bentleyford area of Shropshire is inferred to be depositional, as are those between the Grey and Black Shales and between the Black and Shineton Shales. There is as yet, therefore, no evidence of Maentwrog or Ffestiniog deposition in Shropshire. It is conceivable that the Black Shales may represent further horizons of the Dolgelly stage than those identified, and were it feasible to work the shale laterally along its outcrop, fossiliferous concretions might be found at different stratigraphical levels ; so far, in this section the shales themselves have not yielded trilobites. With the evidence now available, the Dolgelly stage in Shropshire gives two faunal breaks : (1) between the Grey (Orusia) Shales and the Black Shales, of small duration, but marked by a changed shale-lithology and an intervening sand-band ; (2) between the topmost Dolgelly (Black Shales) and the Shineton Shales (Tremadoc), which is likely to be of longer duration. These, with the probable break between the Middle Cambrian and Dolgelly, would appear to indicate that the non-sequences which Cobbold[1] has shown in the Lower and Middle Cambrian of Shropshire recurred in Upper Cambrian times.

In conclusion I would gladly acknowledge assistance in fossil collecting and excavating from Mr. W. Dewar, and in Middle Cambrian fossil naming from Dr. E. S. Cobbold.

[1] *Op. cit.*, 1927, p. 568.

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V.—THE COOMBE ROCK OF THE HAMPSHIRE AND SUSSEX COAST

BY

F. H. EDMUNDS, M.A.

Text-figures 1 and 2

During the re-survey on the six-inch scale of a small area near Fareham, Hampshire, carried out in 1928, a large sheet of Coombe Rock, briefly noted by Mr. H. J. Osborne White,[1] but otherwise unrecorded, was mapped along the southern foot of the Ports Down chalk ridge. Consideration of this deposit opened up the questions of the method of deposition of the extensive sheets of Coombe Rock along the Hampshire and Sussex coast, and of their relationship to coombes in the South Downs.

The Ports Down deposits consist of roughly-bedded chalk and flint rubble, with a proportion of sand; a zone of weathering by decalcification up to 3 ft. thick is generally present. The sheet of rubble, as shown in Fig. 1, extends eastward from about a mile

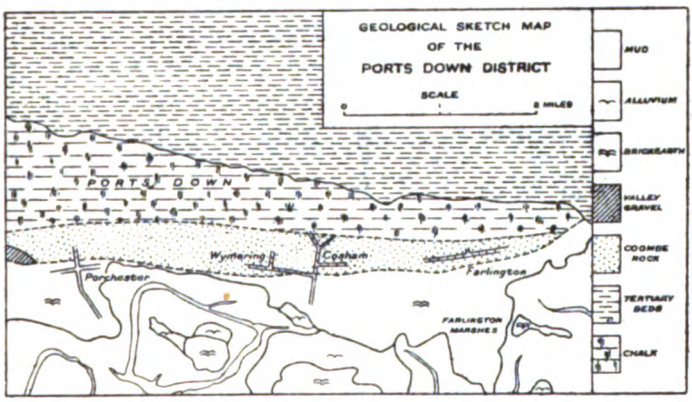

FIG. 1.—*Geological sketch map of the Ports Down district.*

north-west of Porchester, through Cosham to Bedhampton, and southward from about the 100-ft. contour on Ports Down to an unknown distance,[2] disappearing beneath brickearth deposits around Porchester and the Farlington Marshes. It varies in thickness, the maximum being possibly up to 50 ft.; the greatest development appears to run roughly along the 50-ft. contour along Ports Down, and no appreciable thickness is found above the 100-ft. line. Many shallow sections up to 20 ft. deep recently have been exposed,

[1] 'Geology of the Country near Fareham and Havant' (*Mem. Geol. Surv.*), 1913, p. 77.

[2] Clement Reid traces the rubble on the Sussex coast to a distance of 8 miles south; see *Quart. Journ. Geol. Soc.*, vol. xliii, 1887, p. 365.

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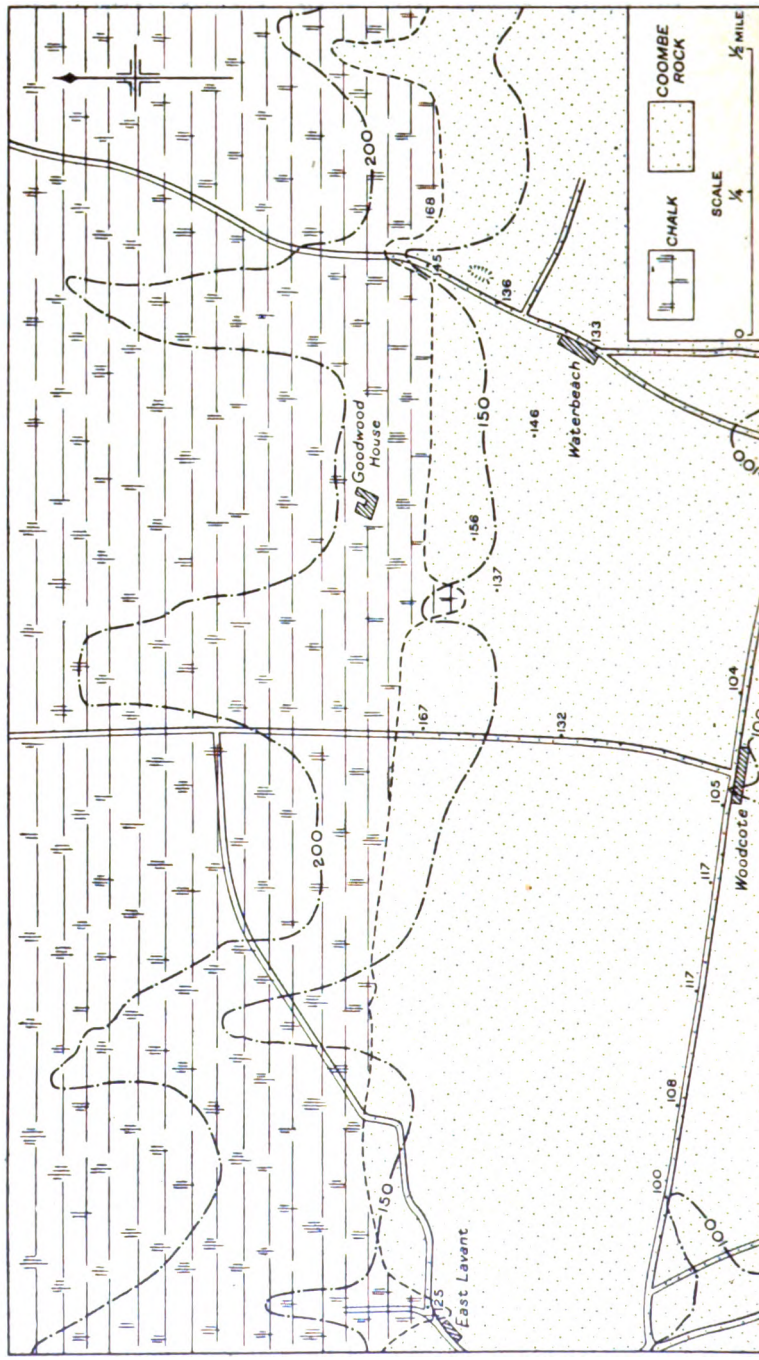

FIG. 2.—*Geological sketch map of the Goodwood district.*

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through building operations. In the Farlington Marshes a trial hole 15 ft. deep did not bottom the rubble.

The presence of this sheet of Coombe Rock is not indicated on the New Series one-inch geological map, Sheet 317, but is shown on six-inch manuscript geological maps Hants 75 and 76, deposited in the library of the Geological Survey and Museum.

The origin of Coombe Rock has been described by Clement Reid,[1] who considered it to have been formed under dry Arctic conditions in an unglaciated region, and its distribution in this district to be due to the confluence of large waste-fans of chalk and flint rubble deposited on the marine platform of the raised beach now traceable from Black Rock, Brighton, westward, the fans being at the mouth of, and their material derived from, coombes in the South Downs. This explanation, however, does not appear satisfactorily to account for the distribution of Coombe Rock in the Ports Down district; a study of land-forms along the Hampshire and Sussex coast where the Coombe Rock is developed also indicates that while Reid's explanation undoubtedly holds in part, it is not adequate for the whole.

Examination of Ports Down shows that no coombes have been developed along the ridge, and it is found that while along Ports Down the Coombe Rock reaches a general height of 100 ft. to 110 ft. above O.D., the surface of the large spread of deposits derived from the valley near Westbourne is but 75 ft. above O.D.

The country eastward of this area shows similar conditions. At West Stoke the surface of the deposits in the coombe is at O.D. 153 ft., while 200 yds. eastward it is at O.D. 186 ft., and continues at that level for over a mile along the Down front, in the absence of any coombes until the valley of the Lavant is reached, where the surface drops to 138 ft. above O.D.

Near Goodwood the Coombe Rock forms a continuous sheet, with neither its northern boundary nor its contour showing any relationship to coombes, a point illustrated by Fig. 2. The northern boundary of the deposit is an almost straight line, with a general level of about 170 ft. above O.D., and the surface slopes gently southward; no trace of a waste-fan is to be found, in fact the reverse, the ground sloping gradually towards the Lavant valley. Waste-fans may be present at the mouths of main valleys, shown fairly well by the Lavant, and excellently by the Findon, valleys; these main valleys are of pre-Coombe Rock age, and themselves collected large quantities of material during the period of the formation of Coombe Rock. Apart from waste-fans such as these, and exceptional ones noted below, fans at the mouth of coombes are generally absent.

Near Brighton thicknesses of Coombe Rock up to 80 ft. have been proved.[2] In connexion with the deposits in this district

[1] *Op. cit.*, p. 364.

[2] 'Wells and Springs of Sussex' (*Mem. Geol. Surv.*), 1928, Wells Nos. 71, 266, 268, 287, 288, 361.

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Mr. H. J. Osborne White[1] remarks " . . . it seems desirable to point out that the sloughing-off of the superficial portions of the Chalk and other formations of the Downs . . . affected the terminal, southern slopes, as well as the lateral slopes, of the downland ridges. . . . Contemplation of the admirable section near Black Rock has left the writer with the strong impression that the bulk of the Coombe Rock there came down the seaward slope of Red Hill in a pasty condition, and guttered over the brow of the old cliff. . . ." Thicknesses recorded from borings at Kemp Town, Hove and Lancing show that the old cliff has been buried in the manner indicated by Mr. White. At Kemp Town Brewery 72½ ft. of Coombe Rock were found. Records of boreholes from Hove, Portslade and Lancing also show considerable thicknesses of Coombe Deposit, resting on other Pleistocene Beds or on beds of Tertiary age. These records, taken in conjunction with records of other boreholes in close proximity, such as those of the Lightfoot Refrigerator Company, Hove, and the Brighton and Hove Laundry,[2] which show Chalk almost at the surface, point to the presence of a cliff feature buried by Coombe Rock, but the problem of the position of such a cliff is complicated by the presence of a fault recognised by Mr. White,[3] which affects the beds of the Portslade district throwing down the shelly clays of the Reading Beds to the south.

Whitaker gives the section of a well sunk at the mouth of the Findon valley[4] of which Mr. White remarks[5] " The existence of so great a thickness of ' drift ' at this spot is hard to reconcile with the form of the ground, which seems to point distinctly to the presence of solid Chalk close to the surface. If the beds above the red sand be Coombe Rock, the well must just miss the buried cliff. . . ." Consideration of this section, taken in conjunction with others referred to, leads to the conclusion that Whitaker's record may be accurate, and that the well in question probably did miss the cliff, which, covered by Coombe Rock, is in this area a well-developed feature.

Around Lancing, Sompting and north of Worthing, well-developed waste-fans opposite mouths of coombes are indicated by the bulging southwards of the 50-ft. contour; one such fan is illustrated by Mr. White.[6]

Considering the sheets of Coombe Rock in Hants and Sussex generally, it is thought that the major cause of their present distribution is solifluction under wet, cold conditions, the process occurring over the whole of the chalk outcrop of the South Downs. By this

[1] ' Geology of the Country near Brighton and Worthing ' (*Mem. Geol. Surv.*), 1924, p. 82.
[2] *Op. cit.*, Wells Nos. 262, 265.
[3] *Ibid.*, p. 65.
[4] ' Water Supply of Sussex (Supplement),' (*Mem. Geol. Surv.*), 1911, p. 246.
[5] *Op. cit.*, p. 84.
[6] *Op. cit.*, p. 84.

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method, the general arrangement and the immense amount of detrital material appear to be accounted for satisfactorily. It is noteworthy that Mr. White states of Black Rock " Blocks of chalk, sarsen, and Eocene iron-sandstone, are freely distributed through the rubble. Sarsens and ironstones up to 6 ft. or more in length . . . strew the shore below the wasting cliff. The number of sandstone boulders here is remarkable. It appears much less probable that they were so thickly congregated on the edge of the Pleistocene cliff, in early Coombe Rock times, that the degradation of the cliff-top which preceded its burial sufficed to precipitate them into the growing mass of Coombe Rock below, than that they, and the associated rubble, were transported hither by solifluction from points more widely distributed on the seaward slopes of the Downs. . . ."[1]

Conditions inducing solifluction are summed up by Dr. Victor Madsen[2], who says " In countries where the mean temperature for the year is below 0°, the earth remains frozen some distance down ; it forms what the Norwegians call ' taele ' . . . Even with a mean temperature of a few degrees of frost, the taele extends to a considerable depth, 150-300 m. In summer, only the uppermost 1-5 m. thaw out. Where there is a taele there is no ground water at all, and there are no springs. Rain and melt water have to ooze away above the taele. As a consequence of this and of the fact that the upper part of the taele thaws, the earth over the taele becomes quite saturated with water and the clay in it assumes a fluid consistence. If the terrain slopes, the earth moves slowly from the higher parts down to the lower ; alternate freezing and thawing contribute to this." With regard to solifluction at the present day, the following quotations are of interest. J. G. Anderson,[3] referring to the work of Dr. S. Hedin in Tibet, remarks, " The description by Hedin clearly shows that the saturated soil actually moves down hill, and that solifluction in those far-extended highlands works on a very large scale, lowering the mountains and filling the valleys." Hedin is quoted as saying " I could not help thinking that the whole bunch of hills would, like a viscous fluid or thick porridge, gradually flatten themselves out to a uniform level."

As distinct from this type of solifluction, Anderson finds that in Bear Island the tendency is for ' mud-glaciers ' to be formed in valley bottoms.[4]

Along the base of Ports Down, and at Goodwood, the slope of the ground appears to be that of a mass of slurry ; apart from other considerations, this slope is too great to be associated with water-deposition, yet too gentle for material formed as a dry scree.

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[1] *Op. cit.*, p. 83.

[2] Summary of the Geology of Denmark, *Danmarks Geologiske Undersögelse*, 1928, p. 85.

[3] ' Solifluction,' *Journ. of Geol.*, vol. xiv, 1906, p. 108.

[4] *Op. cit.*, p. 94.

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The slope of the terrain appears to have influenced strongly the type of solifluction. Along Ports Down, which presented a steep slope ending in a cliff, solifluction occurred equally over the whole area. Along the remainder of the coast-section under discussion, the cliff feature probably induced this type of solifluction along a narrow belt to the north, and becoming degraded itself, was buried. The Ports Down sheet shows, it is estimated, that at least 35 ft. of chalk must have been removed from the whole area of the Ports Down ridge, this implying a considerable recession of the southern face of the hill. On the less steeply-sloping ground inland, streams of mud and rubble may have been formed in slight depressions. Whether or not they formed waste-fans depended on their volume in regard to the volume of material produced by uniform seaward solifluction ; *i.e.*, whether sufficient material was brought down to avoid assimilation by the general mass or otherwise. Main valleys such as those of Findon and the Lavant, with a large area from which to derive material, were able thus to form large waste-fans.

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VI.—*EDESTUS PRINGLEI* SP. NOV.

BY

PROFESSOR D. M. S. WATSON, F.R.S.

Text-figure 1

The remarkable elasmobranchs of the genus *Edestus* have till now been represented in England only by two specimens, a single tooth from Nettlebank, Staffordshire, which is the type of *Edestus triserratus* E. T. Newton,[1] and the type of *E. newtoni* A. S. Woodw.,[2] from the Millstone Grit of Brockholes, Yorkshire, one of the least incomplete specimens known in the world. Both these specimens come from marine horizons in rocks of Coal Measure facies, a feature of special importance. The Russian Edestids were also of marine habit, and there is every reason to suppose that those from the United States were also obtained from marine bands, but unfortunately the details of their mode of occurrence have not in general been recorded.

These facts give special interest to the discovery of *Edestus* in a marine band in the Coal Measures passed through at depths of 1,686 ft. (in No. 1 Shaft) and 1,763 ft. (in No. 2 Shaft) in the sinkings at Cefn Coed Colliery, near Neath, South Wales. Mr. J. Pringle first suggested the possibility of such a find, and subsequently Mr. W. D. Ware, of Ystradgynlais, who had first recognized the presence of the marine bands in the Coal Measures in these sinkings, found three symphysial teeth and one lateral tooth.

The most complete symphysial tooth (Fig. 1, A, B) was formerly in Dr. A. E. Trueman's collection[3], its counterpart being Ba. 1876 in the Survey collection. It is a single, almost complete, element of the row. It may be divided into a crown whose surface is smooth, almost polished, and a root which extends backward and has an irregularly roughened surface, with a superficial and illusory resemblance to calcified cartilage.

The transverse section of the crown is oval, with the extremities produced into ridges bearing the denticulations which form both the anterior and posterior borders.

The anterior border is slightly convex; the posterior, much resembling it distally, sweeps away posteriorly at its base and then turns downward to end on the upper surface of the root.

The extreme tip is truncated, probably by wear; the anterior border bears eleven denticles, all of which are bifid. These denticles are higher than they are thick and are only free at their tips, the

[1] Newton, E. T., 'On the Occurrence of *Edestus* in the Coal-Measures of Britain,' *Quart. Journ. Geol. Soc.*, vol. lx, 1904, p. 1.

[2] Woodward, A. S., 'On a New Species of *Edestus* from the Upper Carboniferous of Yorkshire,' *Quart. Journ. Geol. Soc.*, vol. lxxii (for 1916), 1917, p. 1.

[3] Since this paper was sent to press, Dr. Trueman has kindly presented this specimen to the Geological Survey; its register-number is 49368.

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greater part of their apparent height being only marked off by deep grooves on the surface of the crown. Each is subdivided by a shorter and shallower groove into a large anterior and smaller posterior cusp. These have a rounded margin, and are laterally compressed, so that together they form a wavy edge to the whole tooth.

The posterior denticles are generally similar, but number seventeen, the proximal eight of which, with the exception of the sixth, are unicuspidate.

The polished surface of the crown extends, as a special strip, backward along the upper surface of the root, separated from its denticulated posterior margin by a depressed and roughened area which differs in the character of its surface from all other parts of the tooth.

The root extends backward from the anterior margin of the crown in a direction at about 120° to the latter. For the anterior two-thirds of its length it is wedge-shaped, the slightly swollen sides meeting at an angle, the whole region being designed to fit into the groove on the upper surface of the root of the tooth in front. Posteriorly, where the root forms part of the external surface of the complete row, it becomes oval in section with a rounded lower surface which is actually lozenge-shaped, but must, when complete and uncrushed, have been a V. The great groove which occupies the whole upper surface of the root behind the crown has not been cleared in this specimen.

The Survey specimen 49250 (Fig. 1, C, D) retains only the lower part of the crown, and its root is incomplete posteriorly. The crown differs from that of Dr. Trueman's specimen in being narrower from back to front and in bearing larger denticles. The anterior denticulated border is carried down into a rounded process at its lower end and the posterior border extends far backward, its denticulation being broken off. The strip of root which extends forward into the crown between its posterior end and a special lateral projection is much wider than in the first specimen. The root as a whole is the same as in that specimen, but the groove in the upper edge has been cleared. The anterior part of the root of the first tooth described above fits into this groove accurately and illustrates very well the architecture of the remarkable tooth-spiral.

Specimen 49251 (Fig. 1, E, F) is a complete crown, with the part of the root which lies immediately below it. The apex is truncated by an oblique face, somewhat rounded and grooved, which appears to have resulted from wear. The crown differs from that of Dr. Trueman's specimen and resembles that of the specimen 49250 in that both its borders are concave. The denticulations are smaller and more closely packed than in the first specimen, and are commonly single, though a few on each border are bifid. The anterior projection of the root-surface resembles that of the first specimen.

A single lateral tooth of the *Campodus* type (Fig. 1, G) is represented by the impression of one of its lateral surfaces (specimen

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49252). This tooth is 6 mm. long, its crown being about 1 mm. high, whilst the root is of similar depth. The line of junction of root and crown is sensibly straight, the crown consisting essentially of a series of 13 confluent denticles whose tips form a wavy margin to the whole single ridge. Each denticle is bifid, the cusplets so isolated being often themselves partially divided into two by a groove. The whole thus much resembles a piece of the margin of one of the symphysial teeth on a small scale.

That the three symphysial teeth above described belong to *Edestus* requires no proof; they agree very closely with the type species of that genus, *E. vorax* Leidy. Teeth of *Edestus* are so extremely rare that it is as certain as such things can be that these teeth, despite their differences, belong to the same species. It has then to be considered whether their mutual differences can be explained by two of them belonging to one jaw and the other to its opponent. The only case in which we know both jaws is that of the type specimen of *E. mirus* Hay. Here there is little difference between the teeth of the two jaws; those in one are a little more recurved than in the other, but the variation in this respect is slight, and less than between early and late teeth in the same row.

Thus we may assume that our three teeth illustrate individual variation, perhaps depending on size, the larger and more recent teeth having a crown base longer than their predecessors. The most consistent feature of the teeth is the bifid denticulation.

In any discussion of the specific determination of these specimens it must be borne in mind that they are considerably smaller than other specimens of *Edestus*.

The American species *E. vorax* Leidy and *E. giganteus* Newberry are far larger than ours, *E. heinrichsi* Newberry and Worthen differs entirely in the triangular tooth-crowns. *E. minor* Newberry is closely similar, but is three times the size, and has more slender and more nearly parallel sided tooth-crowns. *E. mirus* Hay is about 1½ times as large and differs in the backwardly turned apices of the teeth, which have a convex anterior and concave posterior margin. *E. serratus* Hay and *E. crenulatus* Hay differ in size, and *E. protopirata* Trautschold, a Russian form, though similar to ours, lacks the bifid denticulation.

The British Millstone Grit *E. newtoni* is totally different, both in crown and root. *Edestus triserratus*, the first tooth found in Britain, differs from our form in that its denticulations are never bifid, but always either undivided or tricuspidate. Its root is wider from side to side and shallower than in our form. Nevertheless, with *E. minor*, it is obviously a close ally.

The teeth from Cefn Coed thus represent a new species, for which I propose the name *Edestus pringlei*, to recall the association of Mr. J. Pringle with the known British specimens of the genus.

This new find is of importance because it is the third occurrence

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of *Campodus*-like lateral teeth in association with the symphysial dentition.

A very complete bibliography of *Edestus* will be found in

Hay, O. P., 1902. Bibliography and Catalogue of the Fossil Vertebrata of North America. *Bull. U.S. Geol. Surv.*, 179.

Hay, O. P., 1929. Second bibliography, etc., of N. America. *Carnegie Institution*, publ. 390.

Explanation of Text-figure 1

Teeth of *Edestus pringlei* sp. nov., from a marine band in the Coal Measures at Cefn Coed Colliery, near Neath, South Wales.

A. Symphysial tooth, right lateral aspect, × 1⅓ diam. Presented by Dr. A. E. Trueman to the Geological Survey, No. 49368, from No. 1 Shaft, depth 1686 ft.

B. Detailed view of the crown of the tooth shown in Fig. A., further magnified.

C. Symphysial tooth, right lateral aspect, × 1⅓ diam. Geological Survey Collection, No. 49250, from No. 2 Shaft, depth 1763 ft.

D. Upper aspect of the tooth shown in Fig. C, apex below, groove for the root of the successional tooth above, × 1⅓ diam.

E. Symphysial tooth, right lateral aspect, × 1⅓ diam. Geological Survey Collection, No. 49251, from No. 1 Shaft, depth 1686 ft.

F. Upper aspect of the crown of the tooth shown in Fig. E.

G. Lateral tooth "*Campodus*," × 2⅔ diam. Geological Survey Collection, No. 49252, from No. 1 Shaft, depth 1686 ft.

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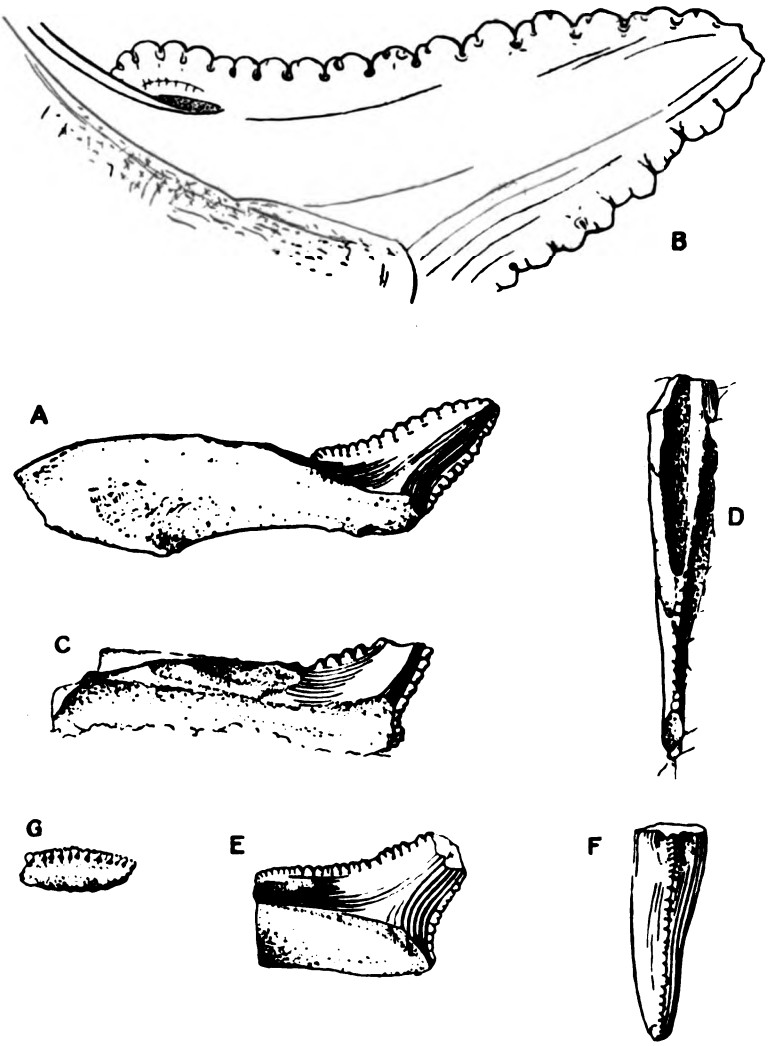

FIG. 1.—*Edestus pringlei* sp. nov.

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VII.—THE APPLICATION OF MECHANICAL ANALYSIS TO GEOLOGICAL MAPPING

BY

H. G. DINES, A.R.S.M., AND F. H. EDMUNDS, M.A.

Text-figures 1 and 2

During the re-survey of the area shown on the New Series one-inch geological Sheet 286 it was found that near Dorking and Reigate separation of the Hythe Beds, Sandgate Beds and Folkestone Beds of the Lower Greensand presented some difficulty. In these districts there is great similarity of lithology throughout the thickness of the upper three divisions; in fact, Drew[1] remarked that "from Dorking to Westgate Street (Westcott) the Lower Greensand, with the exception of the Atherfield Clay, is much the same from top to bottom." In this area part of the Lower Greensand considered by Drew to be Hythe Beds was later thought to be Folkestone Beds by Boulger and Leighton[2]; the area also presented a further problem, one of structure.

Much work has been done in the Reigate and Dorking districts during the past few years by members of the Weald Research Committee of the Geologists' Association, and it was understood that, owing to the absence of fossils, some of these workers were employing with success a method of mechanical sizing of sediments of the Cretaceous Rocks as an aid to geological mapping; the application of this method has been fully described in a recent report of the Weald Research Committee.[3]

In an endeavour to elucidate the structure of the district, particularly in the neighbourhood of the supposed fault described by Topley,[4] generally known as the 'Rookery Fault,' the present writers applied this method. For the purpose fifteen bulk samples of sand were collected, some from known, some from stratigraphically doubtful, horizons, each sample being labelled by a symbol in place of a locality name, the locality names being kept separately. Mechanical sizing of the samples was carried out by one of us without knowledge of the localities, and the results plotted as graphs, which were then referred to their appropriate locations (Fig. 1). The results were such that no indication of the horizon of the sample was given. Three well-marked groups were present, with intermediate types less well marked, but it was found that representatives of Hythe Beds and Folkestone Beds, and also of the doubtful horizons, were included in each group.

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[1] 'Geology of the Weald' (*Mem. Geol. Surv.*), 1875, p. 134.

[2] *Proc. Geol. Assoc.*, vol. xiii, 1893-4, pp. 4-16.

[3] Gossling, F., 'Geology of the Country around Reigate' (Weald Research Report No. 8), *Proc. Geol. Assoc.*, vol. xl, 1929, pp. 197-259.

[4] 'Geology of the Weald' (*Mem. Geol. Surv.*), 1875, p. 233.

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Material from the fifteen original bulk samples collected was tested a second time with new apparatus. The results were comparable as far as grouping was concerned with the first, with three exceptions, but the graphs showed a different form; from which it emerges that should mechanical analysis be employed by more than one person, apparatus of a standardised type must be employed, and also that occasionally the relative forms of graphs of some sediments may vary, according to the accuracy of the meshes of the sieves used.

These facts led to further investigation of the method, sands from the Redhill area being analysed; similar results, negative as regards evidence for use in geological mapping, were obtained (Fig. 2).

In the Weald Research Committee's Report No. 8 referred to above, the following remarks dealing with mechanical analysis as applied to stratigraphy occur[1]:—

> " The information obtained by this method of attack combined with the observations on the lithological characters of the specimens, has enabled the following results to be obtained :—
>
> (1) The lithological and grade characters of the successive strata of the Lower Greensand have been determined.
>
> (2) The Hythe, Sandgate and Folkestone Beds have been subdivided into definite lithological horizons.
>
> (3) Lateral persistence of most of the typical sub-divisions has been established to an unexpected extent.
>
> (4) The modes of lateral change, or development, where these occur, have been demonstrated.
>
> (5) The occurrence of a series of minor cycles of sedimentation between the Weald Clay and the Chalk has been deduced.
>
> (6) Finally, suggestions have been arrived at bearing on the climatic conditions which prevailed in this part of the country in Lower Greensand times."

The following remarks under the heading "Application of Mechanical Analysis "[2] also occur :—

> " The curves shown in the diagram . . . as a rule represent the average percentages of a number of samples."
>
> " Inspection of the diagrams brings out the striking fact that the various divisions of the Lower Greensand have characteristic curves, and that this is true also of the sub-divisions."
>
> " . . . at Redhill the Middle Hythe Sand . . . maintains the fine grade of the Lower Hythe."

With regard to these latter remarks, it has not been made clear on what grounds several samples were associated to produce one curve in such a way as to avoid linking samples of two contiguous divisions or subdivisions. Unless they were taken from a very restricted area of a few yards, either locality or lithology appears to have been the criterion; if the former, the structure of the district must necessarily have been known or assumed; if the latter, the horizon of the bed yielding the samples must similarly have been

[1] *Op. cit.*, pp. 208-209.
[2] *Ibid.*, pp. 209-211.

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known or assumed. Like conditions apply should associated samples have been collected from vertical sections; some method of selection must have obtained to prevent, say, the comparison of a mixture of samples from a 40-ft. face in an extensive sandpit with a mixture from an exposure a foot or two in height. Again, it is not clear on what evidence, other than that gained by the usual methods of field observation, the Middle Hythe Beds were separated from the Lower Hythe Beds in the Redhill district, where both have a similar fine grade.

The present authors are unable to subscribe to the view that "divisions and subdivisions of the Lower Greensand have characteristic curves." Considering the above six points, which appear in the Report under the heading of 'Stratigraphy,' they are unable to find justification for the claim made that these points are established by the evidence gained from a study of lithology combined with mechanical sizing of the sediments. Most of these deductions may be arrived at equally well from field observations alone. The Lower Greensand between Westcott and Redhill consists mainly of quartz sands with silts throughout their thickness; false bedding is present to a marked degree. When traced over their outcrop in Surrey the beds are seen to be exceedingly variable both in the Hythe and in the Sandgate divisions. It would seem to require more evidence than slight changes in lithology and grade of material in a small area like the Reigate district to establish stratigraphical subdivisions such as those of Lower Hythe, Middle Hythe and Upper Hythe Beds.

The authors, while recognizing the value of lithological characters as a guide to mapping in the field, are of the opinion that it is at present unsafe to base any stratigraphical deductions on evidence gained by the application of the methods of mechanical analysis to the Cretaceous Sediments.

Procedure.—The method of procedure adopted consisted of drying and screening the samples, specimens from the Lower Greensand usually carrying so small a percentage of the finest grades as not to need previous washing for the removal of mud; care was taken, however, that the material was not clotted into lumps. The screens used were brass wire meshes of 30, 60, 90 and 120 apertures to the inch. The sizes of the meshes were determined by measurement under a microscope to be 0·65, 0·30, 0·20 and 0·13 mm. respectively.

The method of screening or sifting of sands for the purpose of mechanical analyses is described by Prof. P. G. H. Boswell[1] as wanting in accuracy below ·25 mm., but several small samples taken from one bulk sample gave results which correspond so closely that it seems probable that the degree of accuracy of this method is sufficient for comparative purposes, and therefore for the end in view, namely

[1] 'Sands and Rocks used in Glass Making,' London, 1918, p. 19.

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that of determining whether the various horizons of the Lower Greensand yielded characteristic curves. Again, considering the curves given here, those parts which represent grades greater than ·25 mm. are sufficient in themselves for grouping together the curves of like samples.

Results.—The fifteen samples, referred to above, give curves which, with the exception of two, fall definitely into three groups (Fig. 1).

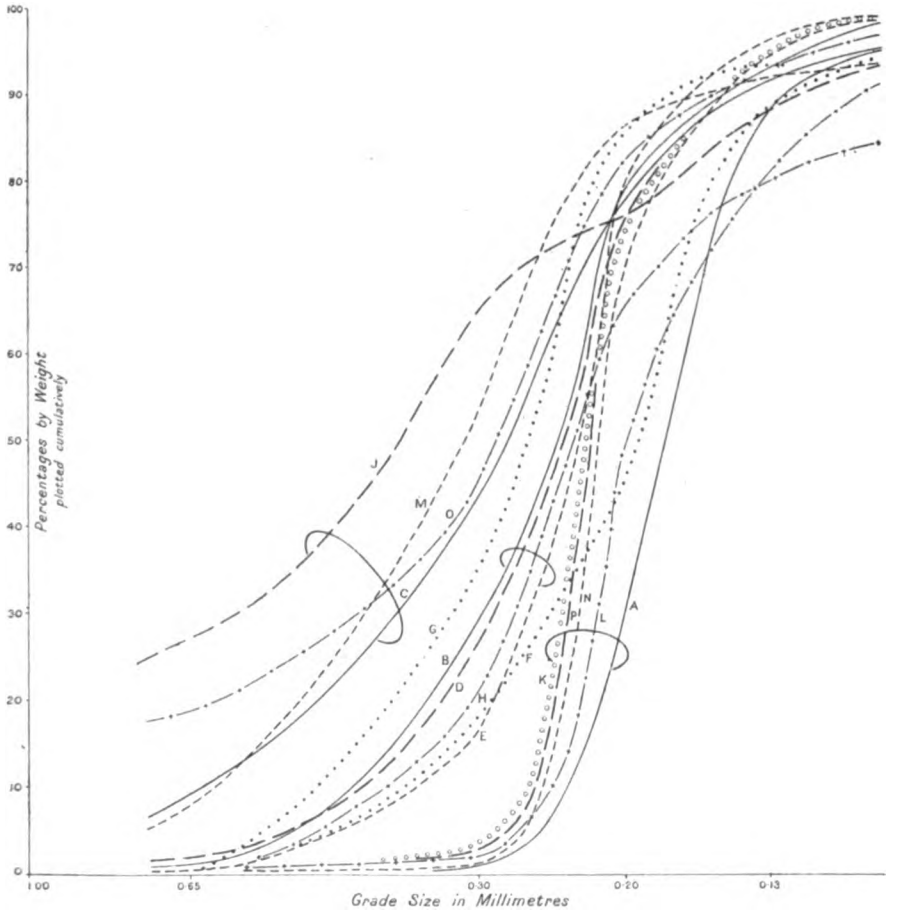

FIG. 1.—*Grading of samples of Lower Greensand, Dorking district.*

The samples from the various formations are distributed amongst the three groups, and it cannot be said that any group is confined to any horizon. The samples from doubtful horizons are also spread over the whole range of the curves. These latter are from horizons which have been variously identified as Hythe Beds and as Folkestone Beds.

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The following tables show the localities and horizons from which the samples were obtained :—

Coarse Group

Sample.	Horizon.	Locality.
C	Hythe Beds, about 20 ft. above Atherfield Clay	Cutting in Stane Street, south of Dorking (Horsham Road).
J	Doubtful. Hythe Beds of Drew, Folkestone Beds of Boulger and Leighton. Base of Folkestone Beds according to Edmunds	Sandpit at "Rookery." Halfway up face and 15 yds. from main road. (See sample L).
M	Middle of Hythe Beds	One-third mile south of Deepdene.
O	Folkestone Beds	North end of Box Hill sandpit.

Medium Group

Sample.	Horizon.	Locality.
B	Near base of Hythe Beds	One-eighth mile north of "Trashurst."
D	Doubtful. *Cf.* sample H	Sandpit at west end of "The Nower," at Milton Street, about 100 yds. north of Bury Hill Lake.
E	Folkestone Beds	North face of north pit in Vincent Lane.
H	Doubtful. Hythe Beds according to Drew and Edmunds. Folkestone Beds according to Boulger and Leighton.	Sandpit on top of "The Nower."

Fine Group

Sample.	Horizon.	Locality.
A	Near base of Hythe Beds ...	Punchbowl Lane, ¼ mile south-west of Park Farm.
K	Folkestone Beds	Lane opposite Place Farm, 150 yds. north of main road.
L	Doubtful. See Sample J	Base of south face of "Rookery" sandpit.
N	Base of Hythe Beds, 5 ft. above Atherfield Clay	Coldharbour Lane, 1½ miles south of Dorking.
P	Folkestone Beds	North end of Box Hill sandpit.

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Samples not falling into the above Groups

Sample.	Horizon.	Locality.
G	Doubtful. See sample H	East end of "The Nower" opposite Ridgeway House.
F	Base of Hythe Beds, about 2 ft. above Atherfield Clay	About 50 yds. south of locality of sample A.

In Fig. 2 is shown a number of curves of samples taken from various horizons in the Lower Greensand east of Reigate. It is obvious from this group of curves that the averages of the Hythe

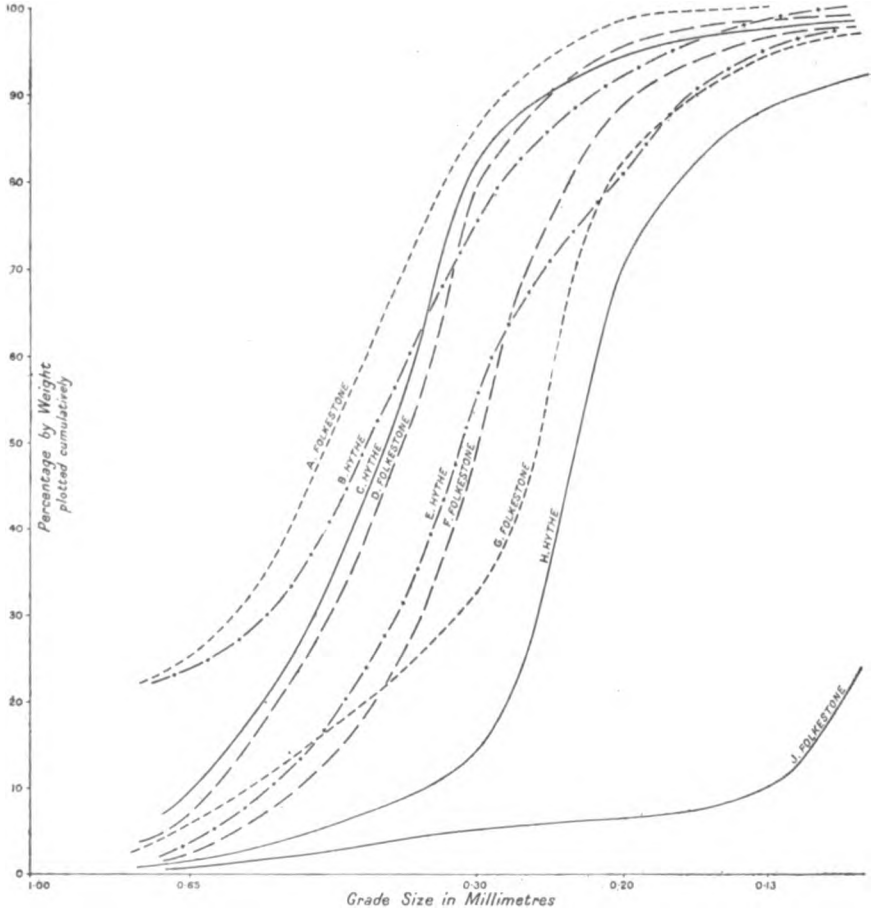

FIG. 2.—*Grading of samples of Lower Greensand, Redhill district.*

samples and that of the Folkestone samples (omitting J) are very similar. The localities and horizons are given in the following list :—

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Sample.	Horizon.	Locality.
A	Folkestone Beds	Martin's Pit, Merstham.
B	Top of Hythe Beds or base of Sandgate Beds	Road-cutting south of Nutfield.
C	Top of Hythe Beds or Sandgate Beds	Entrance to Bletchingley Castle grounds.
D	Folkestone Beds	Old pits west of main (Caterham) road, Godstone.
E	Hythe Beds	Outwood Lane cutting south of Bletchingley.
F	Folkestone Beds	Electricity Works Pit, Reigate.
G	Folkestone Beds	Small pit east of Brewer Street.
H	Top of Hythe Beds	Small sunk lane east of Outwood Lane, Bletchingley.
J	Folkestone Beds	Lane north of Godstone church.

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I.—PLIOCENE SANDSTONE FROM ROTHAMSTED (HERTFORDSHIRE)

BY

H. G. DINES, A.R.S.M., A.M.INST.C.E., AND C. P. CHATWIN, M.SC.

Plate I

1. THE OCCURRENCE OF THE SANDSTONE. By H. G. Dines.

Recent trenching work on the Rothamsted Experimental Farm brought to light a ferruginous sandstone of Pliocene (Red Crag) age. This sandstone was first seen among material thrown up from a trench (18 in. in depth) running from N.E. to S.W. across the field called West Barnfield. The soil and subsoil thrown out from this trench contained angular flints in conspicuous abundance; the whole of that part of the Farm (434 ft. above O.D.) being on ground mapped as Clay-with-Flints overlying Chalk.[1] At two places along this trench, however, the paucity of flints made the excavated material noticeably different from the rest; thus two darker patches were observable along the debris-bordered trench. These were the places at which the ferruginous sandstone was found. Fragments of the sandstone were afterwards found on the field called Sawyers, along the western boundary of the field Long Hoos, and are to be seen in the bank behind the L.M.S. Railway platform at Roundwood Halt, and in some temporary excavations nearby.

The occurrence was noticed by the writer during a re-survey of the Rothamsted ground in connexion with soils. A Pliocene age of the sandstone being suspected, careful search was made for fossils, and several shell-fragments were obtained. Although these fragments showed nothing diagnostic, the finding of fossils in such a position was important, especially since the heavy mineral suite of the matrix, as confirmed by Prof. P. G. H. Boswell, was similar to that of the sandstone at Lenham. It was therefore decided to seek permission from Sir John Russell, Director of the Rothamsted Experimental Station, to conduct further excavations with the object of obtaining more material and details of its mode of occurrence. Accordingly, a part of the trench in West Barnfield was enlarged until an opening that measured 8 ft. by 5 ft. 6 in. at the surface was excavated to a depth of 9 ft. 6 in. The opening thus made showed sections which were different on each of the four sides. Soil and subsoil were seen to an average depth of 18 inches. The main mass of the material beneath this covering was buff-coloured sand with clay, locally stained red. Scattered throughout this material (which in parts was almost entirely sand) were numerous boxstones, but no flints. As minor details it may be noted that immediately beneath

[1] 'The Geology of the Country around Hertford' (*Mem. Geol. Surv.*), 1924; Geol. Map, one-inch New Series, Sheet 239.

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the subsoil, extending along the southern face and a short distance into the western face, was a lenticle of mottled (red, brown, and green) sandy clay, 3 ft. in maximum thickness; also, near the floor of the pit, at the north-west corner, terminating 6 ft. from the surface, was a pocket of large nodular (unrolled) flints with numerous small rounded flint pebbles closely packed, and enclosed in dark buff-coloured sandy clay. A boring tool sunk at the south-east corner of the floor of the pit proved the sandy clay for a further 6 feet; in the north-west corner the tool was sunk for 1 ft. 3 in. into stiff dark clay with small subangular flints. Nowhere was the Chalk reached.

The ferruginous sandstone, which yielded the fossils, was seen to occur as two large blocks embedded in the main mass of buff-coloured sandy clay. One of these roughly rectangular blocks, encountered 3 ft. from the surface, measured 18 ft. 6 in. by 2 ft. by 1 ft. 3 in.; it lay with the long axis directed S.S.W.-N.N.E. and inclined at an angle of 6 degrees from the horizontal; its upper surface (2 ft. in width) sloped east-south-eastwards at an angle of nearly 40 degrees. This upper surface corresponded to the plane of bedding, along which the sandstone could be split. The ends of this block extended beyond the walls of the excavation, but these limits were definitely determined and the whole block broken up and removed. A second block of the same sandstone was encountered 6 ft. from the surface. As much of this as was accessible was broken up and removed. It extended, at a lower level than the first block, beyond the limits of the excavation, and only the following observations were taken; one axis inclined steeply to the south, and the general thickness measured was 18 inches. Fossils from these blocks, after the first set was found, were collected by Messrs. S. W. Hester and W. Dewar, by whom the foregoing details were supplied. Dr. E. M. Crowther, Head of the Chemistry Department at the Rothamsted Experimental Station, afforded many facilities in the carrying out of the work.

2. The Age of the Sandstone. By C. P. Chatwin.

The age of this sandstone was a matter of conjecture at the early stages of the work; but as more material was examined it became apparent, from the frequent occurrence of *Pholas*, the abundance of the remains of *Mytilus edulis*, the presence of isolated plates of *Balanus*, and a small example of *Nassa* that a definitely Pliocene assemblage was being dealt with. On this account as much material as possible was collected, since, when dealing with fossils of this age it is well to bear in mind Harmer's[1] words "... it is necessary to count specimens, so to speak, rather than species." The total number of fossils, mostly fragments, collected was 433.

[1] Harmer, F. W., 'The Pliocene Deposits of the East of England ...,' *Quart. Journ. Geol. Soc.*, vol. liv, 1898, p. 309.

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of which 229 were *Mytilus* and 42 were *Pholas*. Only nine recognizable species were represented. All the fossils were preserved in the medium-grained ferruginous sandstone, of uniform lithology. Most of them were in the form of moulds or casts, but by the use of modelling-wax the details of external morphology could be restored.

At this stage it became evident that, notwithstanding a certain lithological resemblance to the Lenham sandstone, afterwards supported by mineralogical analysis, the sandstone from Rothamsted was not of Lenham age.[1] A sufficient number of specimens was collected to be regarded as a representative sample, but none of these was diagnostic of the Lenham fauna. As was pointed out recently in discussing an assemblage of Pliocene fossils from the North Downs,[2] a typical sample of the Lenham fauna should include *Arca* (*Anadara*) *diluvii* (Lamarck), *Papillicardium papillosum* (Poli), and *Ringiculella lenhamensis* R. B. Newton. These forms are very common at Lenham, where, in association with *Ficula*, *Phorus*, *Triton*, and *Avicula* and southern extinct species of *Pleurotoma* and *Terebra* they impart a facies to the fauna indicating, according to R. B. Newton[3] a southern or Mediterranean origin. So strong is the percentage of extinct (particularly Miocene) forms in the Lenham sandstone that R. B. Newton regarded it as of Upper Miocene age.

In this sandstone from Rothamsted, then, no trace of the characteristic elements of the Lenham fauna was found, as was also the case with the Pliocene fossils from Netley Heath, on the North Downs. The most notable feature of the assemblage, other than the abundance of *Mytilus edulis* Linn., is the comparatively large number (43) of specimens or fragments of *Pholas* (*Barnea*) *cylindrica* J. Sowerby. This is a typical Red Crag species, the occurrence of which gave the first indication of the age of the sandstone. According to the distribution lists of Reid,[4] Harmer,[5] and Tesch[6] its range is restricted to the Red Crag, but a record by R. B. Newton of its occurrence in the Lenham sandstone[7] tended to weaken its value as a guide to age. It became necessary, therefore, to examine the record of its occurrence at Lenham. Newton's record was based on only

[1] F. W. Harmer pointed out that, in Holland " lithologically the Diestien [Lenham age] and Scaldisien [Red Crag (Early Waltonian)] sands are almost identical." 'The Pliocene Deposits of Holland . . .' *Quart. Journ. Geol. Soc.*, vol. lii, 1896, p. 762.

[2] Chatwin, C. P., 'Fossils from the Ironsands on Netley Heath (Surrey),' 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, p. 154.

[3] Newton, R. B., 'The Conchological Features of the Lenham Sandstones of Kent and their Stratigraphical Importance,' *Journ. of Conchology*, vol. xv, 1916, pp. 56-119, pls. 1-4; and *Geol. Mag.*, 1917, pp. 259-269, 320-326.

[4] Reid, C., 'The Pliocene Deposits of Britain' (*Mem. Geol. Surv.*), 1890, p. 273.

[5] Harmer, F. W., 'The Pliocene Deposits of England.—Pt. II,' *Quart. Journ. Geol. Soc.*, vol. lvi, 1900, p. 705; 'A Sketch of the later Tertiary History of East Anglia,' *Proc. Geol. Assoc.*, vol. xvii, 1902, p. 438.

[6] Tesch, P., 'Beiträge zur Kenntnis der marinen Mollusken im West-Europäischen Pliocänbecken,' *Mededeel. van de Rijksopsporing van Delfstoffen*, no. 4, 1912, p. 60.

[7] Newton, R. B., *op. cit.*, 1916, p. 108, pl. 2, fig. 17.

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one example, a specimen in the Geological Survey Museum, registered C. R. 1274. There was clearly some mistake over the identification of this specimen, for it is here shown (p. 5) to be a cylindrical gastropod (Pl. I, figs. 20 and 21). With this—apparently the only—record of *Pholas* (*Barnea*) *cylindrica* from the Lenham sandstone thus accounted for, there is no difficulty in accepting a Red Crag age[1] for the sandstone, especially as this Pholad is accompanied by numerous examples of *Mytilus edulis* Linn., and such forms as *Cardium parkinsoni* J. Sowerby, *Ensis ensis* (Linn.), and *Nassa granulata* J. Sowerby.

The common examples of *Mytilus edulis* vary in size, and in no case are the valves united; otherwise their occurrence with numerous Pholades recalls the association (although under different conditions) of these two forms at Sutton (Suffolk) noted by Prestwich[2] in proximity to an old shore-line. Prestwich remarked that " with the exception of the old shore at Sutton, with its *Mytili* and *Pholades*, it would not be easy to fix upon a place in the Red Crag where the Testacea are on the spot where they lived." In this connexion it is interesting to note that, in addition to the shells of *Pholas* (*Barnea*) *cylindrica*, four of the small accessory plates belonging to this form have been found in the sandstone at Rothamsted.

The number of constituent species in the assemblage of fossils found on this sandstone is limited. On this account, and in view of the extent to which the geographical factor enters into the 'zoning' of the East Anglian Crags, any attempt at correlating the fauna with a subdivision narrower than the Red Crag would seem unlikely to yield satisfactory results. Two considerations, however, seem worthy of discussion. Of the nine recognizable species found in the sandstone from Rothamsted five—*Pholas* (*Barnea*) *cylindrica*, *Ensis ensis*, *Cardium parkinsoni*, *Cerastoderma edule*, *Nassa granulata* —are regarded by Harmer[3] and Boswell[4] as characteristic Waltonian species. Moreover, none of the species noted by Harmer (*op. cit.* p. 713) as becoming more or less common in the later beds of the Red Crag, and also as being absent or rare at Walton, has been found in the sandstone from Rothamsted. These considerations seem to justify the conclusion that this sandstone is of Waltonian age (Upper Pliocene of Harmer).[5]

The fossils from Rothamsted are therefore of the same general age as those found on the North Downs at Netley Heath (Surrey). At the latter locality the assemblage is somewhat different, in that

[1] Searles V. Wood recorded " only a few fragments " from the Coralline Crag. ' A Monograph of the Crag Mollusca,' vol. ii, Bivalves (*Palaeontographical Society*), p. 295, 1857.

[2] Prestwich, J., ' On the Structure of the Crag Beds of Suffolk and Norfolk, Part II,' *Quart. Journ. Geol. Soc.*, vol. xxvii, 1871, pp. 328, 330.

[3] Harmer, F. W., ' The Pliocene Deposits of the East of England, Part II,' *Quart. Journ. Geol. Soc.*, vol. lvi, 1900, p. 712.

[4] Boswell, P. G. H., ' The Faunal Relations of the Crag Deposits of the Bentley District, Suffolk,' *Proc. Geol. Assoc.*, vol. xxxv, 1924, p. 214.

[5] Harmer, F. W., ' The Pliocene Mollusca of Great Britain,' vol. i (*Palaeontographical Society*), 1914, p. 5.

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it is characterized by the abundance of the bivalve shell *Corbulomya complanata* Auctorum, a form not present at Rothamsted; moreover, only one small fragment of *Pholas* (*Barnea*) *cylindrica* J. Sowerby and one example of *Mytilus edulis* Linn. were found at Netley Heath. In addition to the two last-named species, *Cardium* (*Cerastoderma*) *edule* Linn. the small *Pectunculus* and isolated plates of *Balanus* are common to both assemblages. The difference between the two assemblages was doubtless due to different local conditions, most of the Netley Heath fossils being preserved in a conglomerate.

Any discussion as to whether the sandstone at Rothamsted is nearly *in situ* or not[1] may be omitted here.

The following species from the sandstone of Rothamsted have been identified :—

Pholas (*Barnea*) *cylindrica* J. Sowerby. (Plate I, figs. 1-9).

Of this typical Red Crag Pholad 43 examples were collected. These vary considerably in size ; both internal casts and external moulds are preserved. In order to justify the exclusion of *Pholas* (*Barnea*) *cylindrica* from the list of Lenham species, a wax impression taken from the original of R. B. Newton's figure (*Journal of Conchology*, vol. xv, pl. 2, fig. 17) is reproduced here on Plate I. The orientation of the present figure is that usually adopted for gastropods : in the *Journal of Conchology* the figure is placed with the length directed from left to right, after the manner of figuring lamellibranchs. What Newton refers to as " the elongate-concentric ridges crossed by fine striations and best seen at the anterior end " are here interpreted (on the assumption that the shell is a gastropod) as growth-lines (axial) crossed by spiral striae (Plate I, fig. 21).

Mytilus edulis Linn. (Plate I, figs. 10-12).

This is the commonest species found in the sandstone, 230 examples (slightly more than half the total number of fossils found) having been collected. The specimens vary in size and some are fragmentary.

Modiola barbata (Linn.). (Plate I, fig. 13).

The only representative of this species is an external mould of a small right valve.

Ensis ensis (Linn.).

The four examples of this shell are small : the largest mould only just exceeds one inch in length. One external mould of part of a left valve shows the dorsal and anterior margins sharply defined. Two internal casts bear impressions of the teeth.

[1] The recently published ' Discussion on the Alleged Pliocene of Buckinghamshire and Hertfordshire ' (*Proc. Geol. Assoc.*, vol. xl, 1929, p. 357) tends to indicate that there may not be unanimity of opinion on this point.

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Pectunculus glycimeris (Linn.).

Three very small casts are probably referable to this species.

Tellina ? (Plate I, fig. 17).

Several casts of small lamellibranchs may belong to the genus *Tellina*. They show neither dentition nor morphological details and definite determination is therefore impossible.

Cardium parkinsoni J. Sowerby. (Plate I, figs. 14 and 15).

This species is represented by fragmentary impressions from near the ventral margin.

Cardium (*Cerastoderma*) *edule* Linn. (Plate I, fig. 16).

Only one poorly preserved external mould of this species was found.

Modiolaria costulata (Risso).

Three fragmentary moulds are referable to this species: they show only concentric growth-lines crossed by fine radial ridges.

Nassa granulata J. Sowerby. (Plate I, figs. 18 and 19).

Gastropods are very rare in the sandstone. Two specimens can be identified as this species. One consists of the body-whorl and one spiral whorl; the other represents only three spiral whorls.

Natica sp.

The only fragment that can be referred to this genus is a small mould of the three early whorls.

Balanus sp.

Casts and moulds of several isolated plates were collected.

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1

2

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4

5

6

7

8

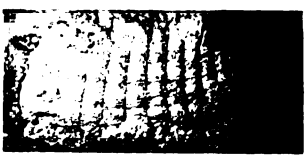
9 (x 3)

10

11

12

13 (x 3)



14

15

16

17

18 (x 3)

19 (x 3)

20 (x 1½)

21 (x 4)

PLIOCENE FOSSILS FROM ROTHAMSTED, ETC.

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EXPLANATION OF PLATE I

Fossils from the Pliocene sandstone of Rothamsted

(All figures are natural size, except where otherwise stated. The specimens are preserved in the Geological Survey Museum, and the numbers at the end of the descriptions are those in the registers of the Palaeontological Department).

Figs. 1-9. *Pholas* (*Barnea*) *cylindrica* J. Sowerby.

Fig. 1. Natural cast of a left valve. [51156].
Fig. 2. Natural cast of a right valve. [51157].
Fig. 3. Natural mould (external), counterpart of the specimen represented by Fig. 1. [51158].
Fig. 4. Wax impression, taken from the mould represented by Fig. 3 [51158].
Fig. 5. Natural cast of anterior part of a left valve. [51159].
Fig. 6. Natural mould of the same (counterpart). [51160].
Fig. 7. Wax impression, taken from previous specimen. [51160].
Fig. 8. Natural cast of an accessory plate. [51161].
Fig. 9. Wax impression of a natural mould (external) of an accessory plate. Enlarged 3 times. [51162].

Figs. 10-12. *Mytilus edulis* Linn.

Fig. 10. Wax impression, taken from a natural mould. [51163].
Fig. 11. Natural cast. [51164].
Fig. 12. Wax impression, taken from a natural mould. [51165].

Fig. 13. *Modiola barbata* (Linn.).

Wax impression, taken from a natural mould. Enlarged 3 times. [51166].

Figs. 14 and 15. *Cardium parkinsoni* J. Sowerby.

Fig. 14. Wax impression, taken from a natural mould (external), near the ventral margin. [51167].
Fig. 15. Wax impression, taken from a natural cast, near the ventral margin. [51168].

Fig. 16. *Cardium* (*Cerastoderma*) *edule* Linn.

Wax impression taken from an external mould. [51169].

Fig. 17. *Tellina ?*

Natural cast of a right valve. [51170].

Figs. 18 and 19. *Nassa granulata* J. Sowerby.

Wax impressions, taken from natural moulds. The lighting of Fig. 18 accentuates the prominence of the axial ridges. Enlarged 3 times. [51171, 51172].

From the Lenham sandstone of Lenham

Figs. 20 and 21. *Bullinella ?*

Fig. 20. Wax impression, taken from the original of R. B. Newton's *Barnea cylindrica* (*Journal of Conchology*, vol. xv, 1916, pl. 2, fig. 17). Enlarged 1½ times. [51173. Formerly registered C R. 1274].
Fig. 21. Lower part of the same wax impression, enlarged 4 times and lit so as to show the spiral striae as well as the growth-lines.

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II.—FURTHER MORPHOLOGICAL STUDIES IN *PALAEOXYRIS*, ETC.

BY

R. CROOKALL, PH.D.

Plates II to V

In *Summary of Progress for* 1927,[1] the writer described several new species of *Palaeoxyris* and *Vetacapsula*, at the same time revising and extending the diagnostic characters of the known Palaeozoic representatives of the genera, while in *The Naturalist* for 1928[2] the related genus *Fayolia* received similar treatment.

Since then many new specimens have been forwarded for examination.[3] The present account, which completes the morphological study of the genera, is concerned with the Mesozoic representatives of *Palaeoxyris*, with the recently described Carboniferous genus *Scapellites*, and the following new species: *Fayolia cambriensis*, *F. eltringhami*, *Vetacapsula hemingwayi* and *Palaeoxyris duni*.

It is also shown that these genera had a much wider geographical distribution than has hitherto been realised, for, though the earliest known specimens were British, German and American, records of one genus or another have recently been made from countries so widely separated as Russia, Bohemia, France, Holland,[4] Korea and Australia.

Vetacapsula, and *Fayolia* are extremely rare, and though *Palaeoxyris* is markedly commoner, most of our museums contain no examples of the genus. *Scapellites* has not yet been recognised in Britain, though, as will be seen, a somewhat similar fossil may have

[1] Crookall, R., 'Palaeozoic Species of *Vetacapsula* and *Palaeoxyris*,' Summary of Progress for 1927 (*Mem. Geol. Surv.*), 1928, part ii, Appendix XIII, p. 87.

[2] Crookall, R., 'The Genus *Fayolia*,' *The Naturalist*, 1928, p. 325.

[3] In the course of these studies, specimens have been examined from all available collections. These include the Museum of Practical Geology and the Geological Survey, London; the Geological Survey (Scottish Office), Edinburgh; the British Museum (Natural History); The Royal Scottish Museum, Edinburgh; the Manchester Museum, University, Manchester; the Bristol Museum; the Dudley Museum; the Barnsley Naturalist and Scientific Society; the Brassey Institute, Hastings; the Public Library and Museum, Brighton; the Department of Geology, University of Birmingham; Hancock Museum, Newcastle-upon-Tyne; the Geological Survey of Sweden; the Riksmuseets Paleobotaniska Avdelning, Stockholm, Sweden; Staatssammlung für Palaeontologie, München; Geologisch-Palaeontologisches Institut der Universität, Gottingen; Preuss. Geologische Landesanstalt, Berlin; Museum für Mineralogie etc., Dresden; Geologisch-palaeontologischen Instituts und Museums, Berlin; Würrt Naturaliensammlung, Stuttgart; Plzen Museum, Plzen, Czechoslovakia; the New York State Museum, University of the State of New York; the Department of Geology, Johns Hopkins University, Baltimore, U.S.A.; the Department of Botany, University of Chicago, U.S.A.; while examples have been seen from the private collections of Mr. H. W. Hughes of Dudley, Mr. W. R. Barker of Barnsley, Mr. W. Baldwin of Burnley, Mr. W. Eltringham of Crawcrook, Dr. J. Walton of Manchester and Herr F. Nindel of Chemnitz.

[4] See Jongmans, W. J., 'Stratigraphische Untersuchungen im Karbon von Limburg (Niederlande), 'Congrès de Stratigraphie Carbonifère,' Heerlen, 1927, published Liége, 1928, pp. 353, 366, 374.

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been observed. By far the richest British locality for these organisms is Coseley, near Dudley, where, during the development of the Openworks, many specimens were obtained in ironstone nodules, from the Coal Measures (Yorkian Series). The great majority of these proved to be the well known British species, *Palaeoxyris helicteroides* (Morris) and were thrown away, but valuable material was very probably discarded at the same time. The Derbyshire and Nottinghamshire coalfield, where the fossils are also found in ironstone nodules, apparently confined to the upper beds of the Yorkian Series, is also rich in the organisms. In some of the claypits of the Derbyshire and Nottinghamshire coalfield examples of *Palaeoxyris*, etc., are the only fossils found, but in others the nodules contain numerous other remains, both vegetable and animal. The late Dr. L. Moysey obtained most of his specimens from this coalfield. No examples of the genera were known from Wales prior to those described in the present studies, while two records only have been made from Scottish rocks. A third is here added.

Continued collecting by Mr. W. D. Ware in the Merthyr area of the South Wales coalfield has brought to light further examples of the genera. From the material collected by Mr. Ware four new species have already been described, namely, *Palaeoxyris warei* (No. R.C. 256), *P. edwardsi* (No. R.C. 255), *Vetacapsula kidstoni* (Nos. R.C. 245-8) and *Fayolia warei* (No. R.C. 253), as well as specimens of Morris' *Palaeoxyris helicteroides*. Since these were described in 1928, several additional examples of *P. helicteroides*, five of *Vetacapsula kidstoni* and one of *Vetacapsula johnsoni* have come to hand. The last named is a new record for the coalfield. It is also evident that, in this district, *Palaeoxyris* is characteristic of the roof of the Soap Vein. All these specimens are in shale.

Of the eight specimens of *Fayolia* known from British Carboniferous rocks (and representing five species), six (including four type specimens) are preserved in the Museum of Practical Geology. The majority of British examples of *Palaeoxyris* and *Vetacapsula* (including most of the types) are in the same collections.

I. The Genus *PALAEOXYRIS*

A.—Mesozoic Species

Before giving a brief account of the known Mesozoic species of *Palaeoxyris*, it is necessary to point out that these organisms may be simulated by other remains of a quite different nature. For example, the specimens figured by Dr. J. Schuster,[1] representing the *Lepidanthium microrhombeum* of Schimper and the *Palaeoxyris microrhombea* of F. Braun have no relationship to *Palaeoxyris* or its allied genera. They are clearly plant remains and exhibit neither the twisted pedicle nor the characteristic pointed beak of *Palaeoxyris*:

[1] Schuster, J., 'Weltrichia und die Bennettitales,' *Kungl. Svenska Akad.*, Handl. xlvi, II, 1911, pl. II, pp. 12, 13-16.

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indeed, the only resemblance shown to the latter genus consists in the presence on the surface of small rhomboids, but they are of a character and origin different from those found on compressed examples of *Palaeoxyris*.

Palaeoxyris jugleri (Ett.)

Pl. III, figs. 3, 4.

This species, which is figured on Plate III, figs. 3 and 4, occurs rarely in the Fairlight Clays (Wealden) of Ecclesbourne, near Hastings, but is fairly common in the Wealden of Deister. At the German locality the organisms are often found occurring in whorls of from six to twelve specimens (see Plate III, fig. 3, where two examples are shown). This feature will be dealt with later when reviewing the nature of the organisms. *P. jugleri* is a large species, having a total length of 16 or more cm., but this depends on the state of preservation of the pedicle which itself may attain 10 cm. The beak is comparatively short (about 3 cm.) and tapers fairly rapidly to form a sharp point. The actual termination, however, is generally hidden by the junction of the specimens composing the whorl and at this point there is often a certain amount of confusion, indicating that the tissues here were of a very delicate nature. Average specimens of *P. jugleri* measure 3 to 4 cm. across the widest part, and the body varies from 4 to 5 cm. in length. About 5 ribs cross the body, separated by 6-10 mm., and taking a distinctly curved course so that, in compressed examples, typical rhomboidal areas are not produced. The angle formed by the ribs is about 50 degrees. Plate III, fig. 4 shows a cast of the species.

Palaeoxyris münsteri (Presl)

Pl. III, figs. 5, 6.

P. münsteri,[1] originally found in the Rhaetic of Bamburg, should probably be united to *P. quenstedti* (Schimper). The body measures about 4 cm. in length and up to 2·3 cm. in breadth. It is traversed at an angle of 30 degrees by about 8 ribs, 3-6 mm. apart. On compression of the capsule in fossilisation, areolations are formed which are up to 10 mm. wide by 5 mm. high. The pedicle is more perfect than the beak. The specimen figured on Plate III at fig. 5 represents a rather small example of the species: that figured on Plate III, fig. 6 is larger, though less well preserved. The species is also known from the Lower Lias of Scania.

Palaeoxyris regularis Brongt.

Pl. V, fig. 4.

Palaeoxyris regularis Brongt.,[2] from the Lower Trias of France, consists of a body from 3·5 to 4 cm. long by 1·3 cm. wide. The

[1] Presl, in Sternberg, *Flora der Vorwelt*, 1820, vol. ii, pl. lix, figs. 10, 11, p. 189.
[2] *Ann. des. Sci. nat.*, I sér., vol. xv, pl. xx, p. 456.

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ribs, which are 5 mm. apart, cross it at a high angle (60 degrees), in compressed examples producing rhomboids 9-10 mm. high by 6 mm. broad.

Brongniart's drawing of his specimen, here reproduced on Plate V, fig. 4, is not entirely satisfactory. The lines radiating from one extremity indicate that this is the beak (they almost certainly represent the decayed beaks of other specimens which either drifted apart or were not preserved), but the characteristic twisting of the segments composing the pedicle is not shown in the figures. Brongniart (*loc. cit.*) regarded *Palaeoxyris* as a fruit and thought that the radiating lines might be the remains of stamens and styles. He also mistook the rhomboids, which result from compression in fossilisation, for adpressed imbricating scales, and figured (*op. cit.*, fig. b) on the same plate what he regarded as an isolated scale, but this has no relationship to *Palaeoxyris* and their association was undoubtedly accidental.

? Palaeoxyris sp.

Pl. IV, fig. 3.

I am indebted to Professor E. W. Berry of Johns Hopkins University, Baltimore, for drawing my attention to a *Palaeoxyris*-like specimen which he collected from the Middle Cretaceous of Kansas, U.S.A. This is figured on Plate IV at figure 3, and has a superficial resemblance to *Palaeoxyris*, though I believe it to be distinct. Professor Berry has not made a study of the specimen, but observes (*in litt.*), ' I got the impression from what appeared to be dicotyledonous venation, that it might represent the case of some aquatic larva of an insect, constructed of leaf material after the manner of certain caddis worms.'

The total length of the specimen is 6·5 cm., of which 7 or 8 mm. appear to form an imperfectly preserved beak, but the absence of a twist on itself casts doubt on its actually representing the beak of one of these organisms. (In this connexion, compare the example of *P. jugleri* figured on Plate III, fig. 4, where the definite twist is seen on the beak at the left hand side). The body is about 2·8 cm. long and the ' pedicle ' 3 cm., but here again the repeated twist in the ribbing characteristic of the pedicles of all known species of *Palaeoxyris* is not observed; on the contrary, the ribs, though showing no displacement, converge gradually towards each other. This region of the Kansas specimen thus corresponds neither to the beak nor to the pedicle of typical Palaeoxyrids. The resemblance to the latter genus is shown only in the body, where three ribs cross it at an angle of 60 degrees. Here again there is a peculiarity, which, however, may be due to accident of preservation. Although the organism appears to be compressed in fossilisation, there is no sign of an areolation such as is common in compressed examples of *Palaeoxyris* (see, for example, Plate II, figs. 4 and 6, where the twisted pedicles are also well shown).

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In the Kansas fossil there are three segments, as in *P. trispiralis* Kidston, a Carboniferous species, but, whereas in the latter the ribs are equidistant, in the present specimen the distance between them varies from 3 to 5 mm. This inequality in the width of the segments does not appear to be accidental, and the only known species of *Palaeoxyris* with alternately broad and narrow segments is the fairly common Coal Measure form, *P. helicteroides* (Morris). In the latter species, however, the body is composed of about 8 segments.

Another interesting feature of the fossil, and one which is especially instructive in view of the fact that the writer has elsewhere[1] expressed his opinion that the various striae found on the body of species of *Palaeoxyris*, *Vetacapsula* and *Fayolia* do not represent original features in the specimens, is the occurrence on this example of distinct striae running parallel to the ribbing. These are clearly shown in the photograph, and are probably due to the resistance offered by the ribs to pressures in fossilisation.

Diagnosis.

Body broadly fusiform, 2·8 cm. long by 1·4 cm. broad, composed of three segments varying in width from 3 to 5 mm. The expansion from the ' pedicle ' to the body is very gradual. The ribs cross the body at about 60 degrees.

Palaeoxyris duni n. sp.

W. S. Dun[2], in 1912, recorded four imperfectly preserved specimens of *Palaeoxyris* (as *Spirangium*) from the Hawkesbury Series (Triassic) at Brookvale, near Manly, New South Wales. They occurred as impressions in shale and were associated with *Phyllotheca*, *Alethopteris sp.*, *Thinnfeldia*, and fish—*Cleithrolepsis*, *Semionotus*, *Dictyopygne* and *Pristisomus ?* He gave the following description (together with a figure) of the most perfect example: ' It has a length, as preserved, of 19 cm., but the stalk-like appendages are imperfect—the inflated vesicle (?) is 10 cm. long, and the spindle-shaped body is traversed by two opposed series of helicidal ridges, each nine in number, dividing the surface into compartments 7 by 10 mm., broader than long on the main mass, though at the extremities the tetragonal compartments are naturally more elongated.'

With regard to the horizon of his specimens, Mr. Dun observes, ' So far as is at present known the shale forms either the basal portion of the Wianamatta Stage or an intercalated bed in the Upper Hawkesbury Sandstone Stage.'

Dr. A. B. Walkom informs me (*in litt.*) that ' The horizon from which the specimens were obtained was about the middle of the

[1] Crookall, R., *op. cit.*, 1928, p. 88.

[2] Dun, W. S., ' Note on the Occurrence of the genus *Spirangium* in the Hawkesbury Series of New South Wales,' *Journ. Roy. Soc. New South Wales for* 1912, vol. xlvi, p. 205, pl. xiv.

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Hawkesbury Sandstone Stage of the Hawkesbury Series in New South Wales, i.e., about 500 ft. above the base of the Hawkesbury Sandstone. These beds, however, are much newer than your Coal Measures, being most probably of middle Triassic age.'

Although details are not given, it is evident that the illustration provided is approximately half natural size, and it is possible to give the following additional features. The body is fusiform, gradually converging at base and apex. The width is 3 cm., and about 2 cm. of beak and 8 cm. of pedicle are preserved. The ribs cross the body at an angle of about 45 degrees, and the segments, which are equally broad throughout, measure about 8 mm. There are two specimens of the organism on the slab of shale figured and they converge by their beaks.

These specimens are important as constituting the first records of the genus from Australia. They clearly represent a new species, and I have named them *P. duni*, after their discoverer. The examples are slightly larger than the Coal Measure species *P. trispiralis* Kidston (of which only two specimens are known). In *P. trispiralis* however, there are three segments, in the Australian species nine. The width of the segments and the angle at which they cross the body correspond fairly closely, but, whereas in *P. trispiralis* there is a sudden transition from beak and pedicle to the body, in the present example the transition is gradual. The specimens are compressed and the rhomboids produced are smaller than in *P. trispiralis*, where they are 16 mm. broad by 11 mm. long.

Diagnosis of *Palaeoxyris duni* n. sp.

Body narrowly fusiform, 9 cm. long by 3 cm. wide. Eight segments, each about 8 mm. broad, compose the body and the ribs form an angle of 45 degrees, by compression producing rhomboids 12 mm. wide by 10 mm. high. The expansion in passing from the pedicle into the body is gradual.

Palaeoxyris sp.

An interesting addition to our knowledge of the Mesozoic representatives of *Palaeoxyris* has recently been made by Dr. S. Kawasaki,[1] Director of the Geological Survey of Korea, and the specimen represents the first record of any of these genera from this part of the world. It is described as follows: 'The specimen is a cast of a fusiform body, 2·5 cm. wide in the middle and 7·5 cm. long, both terminations being unknown. The surface of the whole body is marked with spiral lines, whose ends straighten out into the narrow extremities of the body. The lines are 10 in number and their adjacent ones are apart about 5 mm. The body seems to have been enveloped with 6 ribbon-like valves winding spirally and tightly round the body once and then straightening themselves out at the

[1] Kawasaki, S., 'Some Older Mesozoic Plants in Korea,' *Bulletin of the Geological Survey of Chosen (Korea)*, vol. iv, pt. I, 1925, pl. xlvii, fig. 127, p. 57 (N.B. on p. 57 the plate and figure numbers are given incorrectly as pl. xliii, fig. 117).

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conical elongated extremities. From the above features there is no doubt to assign it to Schimper's genus *Spirangium*, but most of the known species have marked spiral ribs which are represented only by distinct lines in our specimen.'

The specimen stands nearest to *P. jugleri* (Ett.), though it is smaller and the segments narrower. The angle formed by the ribs is about 40-45 degrees (as against about 50 degrees in that species), and there is a fairly sudden expansion from the beak and pedicle to form the body. No striations are mentioned in the description, nor can any be observed in the photograph. It is evident that, though exceedingly rare, except at Deister, Mesozoic species of *Palaeoxyris* were more widely distributed than has hitherto been thought. The example in question was collected in the Daiho Coal Mine, South Heiando, Korea. It was recorded as *Spirangium* and came from the lower division of the Daiho Formation (which lies upon Permo-Carboniferous and Permo-Triassic rocks), and (*op. cit.*, p. 3) it is observed, 'Plant fossils are not poor and in the Daiho Coal Mine an ammonite was found associated with them and was identified by Tokunaga with *Hildoceras Inouyei* Yok. of the Liassic of Nagato, Japan.'

B.—Palaeozoic Species

Palaeoxyris bohemica n. sp.

Pl. IV, figs. 1, 2.

In the collection of the British Museum (Natural History) are four specimens (Nos. V. 3596 a-d) from the Carboniferous of Czecho-slovakia which are distinct from any hitherto described species of *Palaeoxyris*. They are most difficult to photograph satisfactorily, but two are figured on Plate IV at figs. 1 and 2. Though there is a considerable difference in the size of the organisms, their construction is so similar as to leave no doubt that we are dealing with a single species.

Of the two smaller specimens, one (V. 3596 c—Plate IV, fig. 2) is almost complete, the body and most of the pointed beak being shown, but the pedicle is missing (as in all the specimens). The body was about 5 cm. long and the beak about 2 cm., the widest part of the capsule measuring 1·5-1·8 cm. It was traversed at a very low angle (about 15 degrees) by spiral ribs which, owing to crushing in fossilisation, appear to divide it into a number of narrow rhomboids 6 mm. high with sharp lateral angles. Seven or eight such rhomboidal areas are shown. It is in the two smaller specimens only that the margin of the capsule is observable and in these cases not very clearly.

When, as in the two larger examples, the margin is missing, the curious effect shown on Plate IV, fig. 1 has been produced. Here the rhomboids attain a width of 4·5 cm. or so and a height of 1·2 cm., but the angle made by the ribs is the same as in the other examples. One of the larger specimens (V. 3596 b) is contorted so that the ribs

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MESOZOIC SPECIES OF *PALAEOXYRIS*

(The chief diagnostic characters are marked by an asterisk)

	P. münsteri Presl.	*P. jugleri* (Ett.)	*P. regularis* Brongniart	? *Palaeoxyris sp.* (Berry)	*P. duni* Crookall	*Palaeoxyris sp.* (Kawasaki)
Shape of body (fusiform) ...	narrow	broad*	narrow	broad*	narrow	broad
Length of body	3–4 cm.	6 cm.	3·5–4 cm.	2·8 cm.*	9 cm.*	5 cm.*
Width of body	1·2–2·3 cm.	1·7–3·5 cm.	1·3 cm.	1·4 cm.*	3 cm.	2·5 cm.
No. of segments	7*	4–6 *	4*	3*	8*	6
Width of segments	3–6 mm.	10 mm.*	5 mm.	3–5 mm.	8 mm.	5 mm.*
Angle of ribs	30*	50*	60*	60*	45*	40–45*
Expansion from pedicle to body	gradual*	sudden*	very gradual*	very gradual	gradual	fairly sudden
Rhomboids, width	10 mm.	curved	6 mm.	?	12 mm.	?
Rhomboids, height... ...	5 mm.		9–10 mm.		10 mm.	
Figured...	Pl. III, figs. 5,6	Pl. III, figs. 3, 4	Pl. V, fig. 4	Pl. IV, fig. 3	*J.R.S.N.S.W.*, xlvi, 1912, pl. xiv.	*B.G.S.C.* (*K.*), iv, I, 1925, xlvii, fig. 127

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are somewhat curved and the angles bluntly rounded, but the other (V. 3596 a—Plate IV, fig. 1) has straight ribs and, though incomplete, shows part of 10 or 11 rhomboids. Although 14 cm. long, the specimen, as preserved, does not include the whole body, while both beak and pedicle are missing. The complete organism must therefore have been very large. *P. bohemica* could not be confused with any other species of *Palaeoxyris*.

I forwarded photographs of the above specimens to Dr. F. Němejc, Keeper of the Palaeobotanical Department of the National Museum of Czechoslovakia at Prague. He observes (*in litt.*) ' The Prague Museum contains no examples of these organisms, but in the Museum in Plzen are three specimens, all of them in cannel coal (' Plattenkohle ') from the Coal Measures of Nyrany near Plzen. Two of them are similar to the photograph of *Palaeoxyris bohemica* British Museum No. V. 3596 c, one measuring 5 cm. long by 1·8 cm. broad with 10 ribs crossing the capsule half a cm. apart, and the other 6 cm. in length by 1·5 cm. broad with 12 ribs separated by ·5 cm. The third specimen resembles the photograph of *P. bohemica* British Museum No. V. 3596 a, but is somewhat larger though incomplete. It is about 5 cm. broad and 7 ribs are preserved, separated by from 2·5 to 3 cm. The specimens are named '*Gyrocalamus Fayolia*' and are the only ones I have seen from Bohemia.'

Diagnosis of *Palaeoxyris bohemica* n. sp.

Body narrowly fusiform, 5 to 14 or more cm. long, 1·5 to 5·0 cm. wide. The beak is more than 2 cm. long, probably pointed. Ribs cross body at about 15 degrees, and by compression produce rhomboids 6-15 mm. high by 18-45 mm. wide, the lateral angles being sharp.

Palaeoxyris helicteroides (Morris)

An unusually large specimen of this species—the largest I have seen—is preserved in the Hancock Museum, Newcastle-upon-Tyne. It was collected by Mr. W. Eltringham from the Crow Coal (Yorkian Series) at the Phoenix Brickyard, Crawcrook, Durham. The beak and apical portions are missing, but the full width is shown, and measures 3·8 cm. Average specimens of this species measure 1·2 cm. wide, while the largest I have hitherto seen was 3 cm. across. The width of the segments is correspondingly great. Whereas the broader bands usually measure 4-5 mm. and the narrower 1-1·5 mm. across, in this example the broader segments are up to 10 mm. and the narrower 4 mm. across. I have no doubt, however, that the specimen belongs to *P. helicteroides*, which is the only known Palaeozoic species with alternately broader and narrower segments. About 2 cm. of the twisted pedicle are preserved. The surface bears striations both parallel and at right angles to the ribbing.

Another specimen of the same species, collected by Mr. Eltringham and at present preserved in his private collection, illustrates the

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great variation which can occur in the proportion between the length and breadth of these organisms. In this instance the body is rather less than 5 cm. long by more than 3 cm. broad.[1] It is evident that the Crow Coal contains exceptionally large examples of *P. helicteroides*, for another specimen of Mr. Eltringham's measures 2·7 cm. across and the body is 6 cm. long. Unfortunately the Phoenix Brickyard is no longer working. All the specimens are in ironstone nodules.

An example of *Palaeoxyris* which I refer to *P. helicteroides* has been kindly forwarded for examination by Professor A. C. Noé of Chicago University. It is from the well-known locality of Mazon Creek, the horizon being the lowest strata of the Middle Coal Measures (or just above the Millstone Grit). Like so many of the British examples of the genus, it is contained in an ironstone nodule, and, also like them, there is a coating of a white substance which (in British specimens) proved to be ferrous carbonate. The specimen is quite typical, with well preserved beak and pedicle and the usual enlarged region above the centre of the body.

Palaeoxyris prendeli Lesqx.

Pl. II, fig. 3.

The Royal Scottish Museum contains an interesting specimen of *Palaeoxyris prendeli* Lesqx. in an ironstone nodule (No. 1911.8.3; see Plate II, fig. 3). It came from the Yorkian Series of South Staffordshire, and measures 1·0 cm. across the widest part of the body (the smallest example of this species hitherto recorded being 1·2 cm. across). The body is about 2·5 cm. long. Six segments are shown: they are not quite equal in width, but this is due to an accident of preservation. The ribs take an angle of about 55 degrees —much steeper than in the somewhat similar *P. carbonaria* (where the angle is about 30 degrees), and the expansion from the pedicle to the body is sudden (whereas in *P. carbonaria* it is gradual). The beak is not preserved.

The most noteworthy feature in this specimen consists in the striations present: they are strongly marked and stand practically at right angles to the ribs. In support of my contention that the striations occurring on various examples of these organisms are not original markings, it may be pointed out that they are never seen in undoubted Mesozoic species and that transfer preparations made from the specimens show no corresponding lines. I have now obtained transfers from three species—*Palaeoxyris jugleri* from the Wealden of Deister, *Palaeoxyris helicteroides* from the Coal Measures of Great Britain, and *Fayolia sterzeliana* from the Lower Westphalian of Karsten Zentrumgrube near Beuthen, Upper Silesia. Cellular tissue or striae are not shown in any instance.

[1] Associated with this specimen are Ostracods which are identified by Dr. Stubblefield as *Cytherellea* sp.

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Professor Pruvost informs me (*in litt.*) that specimens he has in hand from the Coal Measures of Belgium include examples of *P. prendeli* and of *P. appendiculata.*

Palaeoxyris trispiralis Kidston

Two examples only of this well defined species are known to me—the type specimen[1] (British Museum, Natural History, part and counterpart Nos. 1179, 6364) and a specimen which came from below the Top Hard Coal (Yorkian Series) north-west of Ilkeston, Derbyshire (Museum of Practical Geology No. 13519). Although in 1909 Mr. W. H. Sutcliffe[2] recorded *P. trispiralis* from the Second Grit Flagstone of Ashworth Moor, near Rochdale (Manchester Museum No. L. 9128), a fossil which, from the writing on the label has evidently been identified by Kidston as *P. trispiralis*, I regard it as distinct.[3]

The Derbyshire specimen is smaller and broader in proportion to its length than is the type, but the characteristic three segments composing the body leave no doubt as to its identity. In the discussion following Dr. Moysey's paper in 1910[4] Professor W. W. Watts commented on the variation in size of the specimens included under various species of *Palaeoxyris*, and though this point will be dealt with more fully in a subsequent paper, continued work has shown that the variations within all species are even greater than was at first realised. The discovery of a second example of *P. trispiralis* illustrates this. The dimensions of the two specimens are as follows :—

	Type specimen	Derbyshire specimen
Width	3·5 cm.	2 cm.
Length of body	9·0 cm.	4 cm.
Rhomboids, breadth	16-18 mm.	11-14 mm.
,, length	10-12 mm.	6-7 mm.

The angle at which the ribs cross the body is the same in both examples—30-40 degrees. In the Derbyshire specimen about 2 cm. of the sharply pointed beak is preserved.

Palaeoxyris pringlei Crookall

Pl. II, fig. 4.

Hitherto there have been two records only of *Palaeoxyris* from Scotland, while the genera *Vetacapsula*, *Fayolia* and *Scapellites* have

[1] Kidston, R., *Proc. Roy. Phys. Soc. Edin.*, vol. ix, 1886, pl. i, fig. 7, p. 64.
[2] Sutcliffe, W. H., *Lancashire Naturalist*, July, 1909, p. 117, text-fig. 3, p. 116.
[3] Crookall, R., *op. cit.*, 1928, pp. 101-2.
[4] Moysey, L., *Quart. Journ. Geol. Soc.*, vol. lxvi, 1910, p. 339.

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yet to be found. *P. carbonaria* Schimper is known from the Lanarkian Series at Woodhead Quarry, Kilmaurs, Ayrshire, and the same species from Coal Measure rocks in Sliddery Water Head, Ayrshire.[1]

Particular interest therefore attaches to a third example (Geological Survey, Scottish Office, No. T. 4014 B) of *Palaeoxyris* collected by Mr. D. Tait from the Barren Red Measures in the Barony Pit Shaft Sinking, 1½ miles west of Auchinleck. This I identify as *P. pringlei*, and it represents the second known example of the species. The type is preserved in the Museum of Practical Geology (No. 38557).

The specimen (figured on Plate II, fig. 4) is compressed and incomplete, the beak being absent. In the type specimen, however, the beak was fairly well preserved and the pedicle absent. Here the pedicle is rather more than 2 cm. long. In all essentials the Ayrshire example agrees well with the type. The broadly fusiform body is traversed by 12 or more ribs which cross it at an angle of about 15 degrees, forming, by compression, rhomboidal areas which are broader than long. About 18 mm. of the body is preserved and the maximum width is 1 cm. The segments are equally broad, 1 mm. or slightly less across.

Palaeoxyris carbonaria Schimper

Pl. II, figs. 5, 6.

When dealing with this species in 1928,[2] I pointed out that the collection of the British Museum (Natural History) included two specimens showing agreement with *P. carbonaria* in form and size, and in the angle formed by the ribbing but which differed in the much closer approximation of the ribs. I suggested that these should be designated *P. carbonaria forma* α. Whereas in typical examples the segments are about 2 mm. broad, in these specimens they are about 1 mm. broad.

Another example of this form has now been found in the collection of the Museum of Practical Geology (part and counterpart, Nos. 30,252, 30,253 : the latter is figured on Plate II, fig. 5). It is from the Thick Coal (Yorkian Series) of Coseley, South Staffordshire. The specimen is about 9 mm. wide and the body 2·5 cm. long. It is uncompressed and part of both the beak and pedicle is preserved. The ribs are 1 mm. apart, whereas in the typical example of the species figured on Plate II, fig. 6 (Museum of Practical Geology, No. 12,602) they are separated by 2 mm. In the latter specimen the beak is not preserved, but the pedicle is clearly seen. *P. carbonaria* is very rare in Britain though it is common in America where it was described as *P. appendiculata* by Lesquereux.[3]

[1] Kidston, R., *op. cit.*, 1886, p. 62 ; and Tyrrell, G. W., ' The Geology of Arran,' 2nd. ed. (*Mem. Geol. Surv.*), 1928, p. 72.

[2] Crookall, R., *op. cit.*, 1928, p. 100.

[3] Lesquereux, L., *Geol. Surv. Illinois*, vol. iv, 1866, p. 464, pl. xxvii, fig. 11.

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As I have seen no transitional forms between the typical *P. carbonaria* and the form here distinguished as *P. carbonaria forma* α, I am not entirely satisfied that the latter is not a distinct species, but these organisms are very variable and too fine distinctions cannot be drawn.

It should be pointed out that while R. Kidston,[1] L. Moysey[2] and the writer[3] regarded *P. carbonaria* as synonymous with Lesquereux' *P. appendiculata*, D. White[4] and P. Pruvost[5] consider them to be distinct. Pruvost points out that a specimen recorded by him from the Coal Measures of the north of France agrees with the British examples (named *P. carbonaria*) and these he regards as representing *P. appendiculata*, the distinguishing features cited being the very serrated ribs and the very long straight pedicle, while these forms are from earlier horizons than *P. carbonaria* (which was from Stephanian of Wettin, Saxony).

ADDITIONAL PALAEOZOIC RECORDS OF *PALAEOXYRIS*

P. helicteroides (Morris)

horizon : Ruler Coal (Yorkian Series).
locality : Claypit, Phoenix Brickworks, Crawcrook, Co. Durham.

horizon : Crow Coal (Yorkian Series).
locality : Claypit, Phoenix Brickworks, Co. Durham.

horizon : ' Coal Measures ' (? Yorkian Series).
locality : Deepfields, South Staffordshire (Dept. of Geology, University of Birmingham).

horizon : ' Coal Measures ' (? Yorkian Series).
locality : Holly Hall, South Staffordshire (ditto).

horizon : at a depth of 664 yds. (Yorkian Series).
locality : Cefn Coed Sinking, near Swansea, South Wales (R.C. 1084).

horizon : at a depth of 728 yds. (Yorkian Series) (Four-feet Cornish Vein).
locality : ditto (R.C. 1205).

horizon : 93 yds. below No. 2 Rhondda Seam (Staffordian Series).
locality : ditto (R.C. 779).

horizon : lower part of Middle Coal Measures.
locality : Mazon Creek, Illinois, U.S.A. (A. C. Noé).

P. appendiculata Lesqx.

horizon : Coal Measures.
locality : Belgium (P. Pruvost, *in litt.*).

horizon : Coal Measures.
locality : North of France (ditto).

horizon : Middle Coal Measures.
locality : Mazon Creek, Illinois, U.S.A. (L. Lesquereux).

[1] Kidston, R., ' On the Species of the Genus *Palaeoxyris* Brongniart occurring in British Carboniferous Rocks,' *Proc. Roy. Phys. Soc. Edin.*, vol. ix, 1886, p. 61.

[2] Moysey, L., ' On *Palaeoxyris* and other allied fossils from the Derbyshire and Nottinghamshire Coalfield,' *Quart. Journ. Geol. Soc.*, vol. lxvi, 1910, p. 330.

[3] Crookall, R., *op. cit.*, 1928, p. 100.

[4] White, D., ' Fossil Flora of the Lower Coal Measures of Missouri,' *U.S. Geol. Surv.*, vol. xxxvii, 1889, p. 274.

[5] Pruvost, P., ' La faune continentale du terrain houiller du nord de la France ' *Mém. Carte. Géol. Dét. de la France*, 1919, p. 450.

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P. carbonaria Schimper

horizon : ' Coal Measures ' (? Yorkian Series).
locality : Deepfields, South Staffordshire (Department of Geology, University of Birmingham).

horizon : Thick Coal (Yorkian Series).
locality : Coseley, Dudley, South Staffordshire (Museum of Practical Geology, No. 30,253).

horizon : Ten-foot Ironstone Measures (Yorkian Series).
locality : Coseley, Dudley, South Staffordshire (ditto, No. 12,602).

horizon : Coal Measures.
locality : Upper part of Burn ' B,' Sliddery Water Head, Ayrshire (Geological Survey, Scottish Office).

horizon : Stephanian.
locality : Wettin, Saxony.

P. cf. carbonaria Schimper

horizon : at 647 feet from surface (Keele Group).
locality : Claverley Borehole, 5 miles east of Bridgnorth, Shropshire (recorded by R. Kidston, *Trans. Roy. Soc. Edin.*, vol. li, 1917, p. 1079).

P. trispiralis Kidston

horizon : Below Top-hard Coal (Yorkian Series).
locality : North-west of Ilkeston, Derbyshire (Museum of Practical Geology, No. 13,519).

P. prendeli Lesquereux

horizon : Coal Measures.
locality : Limbourg (P. Pruvost, 1927).

horizon : Coal Measures.
locality : Belgium (P. Pruvost, *in litt.*).

P. intermedium (Lesquereux)

horizon : Coal Measures (Sub-conglomerate).
locality : Pittston, U.S.A. (L. Lesquereux).

P. multiplicata (Lesquereux)

horizon : Middle Coal Measures.
locality : Mazon Creek, Illinois, U.S.A.

P. pringlei Crookall

horizon : at approx. 52''' 3' 6'' in the Barren Red Measures.
locality : Barony Pit Shaft Sinking, 1½ miles west of Auchinleck, Ayrshire (Geological Survey, Scottish Office, No. T. 4014 B).

P. bohemica Crookall

horizon : Coal Measures.
locality : Czechoslovakia (Collection of British Museum, Natural History, Nos. V 3596 a, b, c, d.).

horizon : Coal Measures.
locality : Nyrany, near Plzen, Bohemia (Collection of Plzen Museum, Czechoslovakia—*fide* F. Němejc).

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Palaeoxyris sp.

horizon : Blindstone Coal (Yorkian Series).

locality : Heasanford Quarry, Burnley, Lancashire (Collection of W. Baldwin, Burnley).

horizon : at depth of 664 yards (Yorkian Series) (Soap Vein).

locality : Cefn Coed Sinking, Swansea, South Wales (R.C. 1082, 1083).

horizon : roof of seam No. 6 (Coal Measures), at 1,100-1,050 and at 1,150 metres.

locality : Puits No. 10 (Grisoeuil) de la Compagnie de Charbonages Belges (Collected by P. Pruvost—*Ann. de la Société scientifique de Bruxelles*, T. xlii, pt. i, Doc. et Comptes rendus, 1922, p. 153).

II. The Genus *SCAPELLITES*

Scapellites cottoni Pruvost

Pl. V, figs. 1, 2, 3.

Curious specimens found by Dr. A. Renier in the Belgian Coal Measures were described in 1922 by Professor P. Pruvost[1] of Lille under a new generic name *Scapellites* as *S. cottoni*. I am glad to be able to reproduce Professor Pruvost's photographs of these organisms as it is possible that they occur in the British Coal Measures but have been passed over by collectors. Mr. W. Hemingway informed me some time ago that the Gerrard Collection in the Wigan and District Mining and Technical College used to contain an organism like a spiral branching ribbon. Along with other marine fossils, it came from the ' Marine Band Series ' of the Ashton Moss Colliery Sinking. This was possibly either an example of Pruvost's species or a closely allied form, but the Gerrard Collection has been moved several times in recent years, and the specimen cannot at present be found.

Examples of *Scapellites* consist of fusiform capsules which occur as scattered flattened impressions (Plate V, fig. 1). In length they average 16 mm. and in breadth 4 mm. Pruvost points out that, as in *Palaeoxyris*, etc., the surface is not carbonaceous. The whole capsule consists of 12 or more narrow longitudinal twisted filaments which are laterally united. The capsules are longitudinally twisted through half a turn so that the filaments are spirally disposed around the longer axis. As the impressions are always flattened the crushed upper and lower surfaces are seen at the same time, the lower filaments crossing the upper and giving the effect of diamond shaped areas. In some cases (Plate V, fig. 3) the filaments have become dissociated and spread out and Professor Pruvost suggests that this was connected with the dehiscence of the capsule. He also points out that some examples suggest that they were originally united by their pedicles in groups. The genus is distinguished by the zig-zag filament ' twisted a number of times on itself like the thread in a skein of wool.' *Palaeoxyris sp.* has been found in the roof of

[1] Pruvost, P., *Ann. de la Société scientifique de Bruxelles*, Tome xlii, 1922, pt. I, Documents et Comptes rendus, pp. 150-153, pl., figs. 1-4.

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the same seam at this pit. Professor Pruvost informs me (*in litt.*) that he has a second and smaller species of *Scapellites* to describe from the Coal Measures of Belgium.

horizon : 1,150 metres (Coal Measures).
locality : Puits No. 10 (Grisoeuil) de la Compagnie de Charbonages Belges.

III. The Genus *FAYOLIA*

Fayolia cambriensis n. sp.

Pl. III, figs. 2 a, b.

A very fragmentary specimen of *Fayolia*, nevertheless representing a distinct species, preserved, together with its counterpart, in the Museum of Practical Geology (No. 48521) is figured on Plate III at figs. 2 a, b. Only about two spiral turns are present, and the specimen, being incomplete, shows no sign of tapering. It stands nearest to *F. sterzeliana* Weiss (which, being incomplete, was also described as cylindrical), but with important differences. As in *F. sterzeliana*, the spine-scars are about 1 mm. in diameter, but, whereas in that species 5 scars occupy 8 or more mm., in the present specimen 5 scars (the maximum number shown) occupy 6 mm. Successive rows of spine-scars in *F. sterzeliana* are about 8 mm. apart, while in the specimen in hand they are only 4-5 mm. apart. The total length of the organism preserved is about 2 cm., but the entire width is not shown at any point. The collarette was near one suture, and its margin was probably entire. In *F. sterzeliana* the ribs cross the body at an angle of about 15 degrees : in this specimen the angle is markedly lower (about 8 degrees). Altogether the fossil is smaller than Weiss's species. Although it is preserved in a fine shale there is no indication of striation.

Diagnosis of *Fayolia cambriensis* n. sp.

Body probably fusiform, more than 2·0 cm. long and more than 1·4 cm. wide. Spine-scars about 1 mm. in diameter, 5 scars occupying about 6 mm. Successive rows of spine-scars 4 or 5 mm. apart. Collarette near one suture, margin probably entire. Ribs cross body at about 8 degrees.

horizon : Mynyddislwyn Seam (Radstockian Series).
locality : Gwernau Level (Mr. Walker's), ¾ mile S.E. of Maes-y-cwmmer, and ¼ mile E. of the Boot Hotel, Aberdare, Mon.
Collected by J. Pringle.
Collection : Museum of Practical Geology, No. 48521.

Fayolia eltringhami n. sp.

Pl. III, fig. 1.

Mr. W. Eltringham's collection contains a small rather badly preserved example of *Fayolia* in an ironstone nodule, representing the first record of the genus from the Durham coalfield. This is figured

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on Plate III at fig. 1. The two tapering ends are missing, so that it appears to be cylindical, as in several other imperfectly preserved specimens (e.g., *F. crenulata* Moysey, *F. sterzeliana* Weiss, and *F. cambriensis* Crookall). About 3·2 cm. of the body remains. This is by far the narrowest known species of *Fayolia*. Whereas *F. warei* Crookall measured 1·3 cm., *F. moyseyi* Pruvost 1·4 cm., and *F. dentata* Renault and Zeiller from 1·5 to 16 cm. across the widest part, the present specimen has a maximum width of 4 mm. only. Five or six turns of the spiral are present, and the ribs cross the body at an angle of about 15 degrees. The segments are similarly narrower than in any other known species, being from 2 to 3 (never more) mm. wide. The collarette is not clearly shown owing to the state of preservation, but it was probably nearer to one suture, the margin being entire. Only one spine-scar is clearly shown, and this corresponds in size with the rest of the specimen, being about half a millimetre in diameter. In *F. warei* the spine-scars are mere points (a quarter of a millimetre in diameter) but in the other known species they are markedly larger than in either *F. warei* or *F. eltringhami*. Mr. Eltringham informs me that his specimen will probably be given to the Hancock Museum.

Diagnosis of *F. eltringhami* n. sp.

Body fusiform, at least 3·2 cm. long and 4 mm. broad. Five or six spiral turns form an angle of 15 degrees. Segments not exceeding 3 mm. in width. Collarette probably nearer to one suture and entire. Spine-scars small, about half a millimetre in diameter.

horizon: Crow Coal (Yorkian Series).
locality: Phoenix Brickyard, Crawcrook, Durham.

Fayolia sterzeliana Weiss

Pl. IV, fig. 4.

In 1920, Herr F. Nindel[1] published a figure of the first specimen of *Fayolia sterzeliana* in which the collarette was preserved. The example came from the same horizon and locality as the type, i.e., the Upper Culm of Borna, near Chemnitz. In my paper of 1928,[2] these beds were referred to the Lower Carboniferous, but Herr Nindel points out (*in litt.*) that they belong to the lower part of the Upper Carboniferous.

The specimen is uncompressed, and though incomplete (measuring 9 cm. in length by 2·5 cm. in breadth) is well preserved. It is somewhat larger than Weiss's example, the segments being 12 to 14 mm. wide, whereas in the latter they were 6-10 mm.[3] They bear

[1] Nindel, F., 'Ein Beitrag zur *Fayolia sterzeliana* (Ch. E. Weiss) aus dem Ober-Kulm von Chemnitz-Borna' *Bericht der Naturwissenschaftlichen Gesellschaft zu Chemnitz*, 1920, pp. 50-54, text-fig. II, p. 51.

[2] Crookall, R., 'The Genus *Fayolia*,' *The Naturalist* for Nov. and Dec., 1928, pp 361, 365.

[3] Owing to a misprint, the width of the segments of Weiss's specimen, as given in my table of species (*op. cit.*, 1928, p. 366) has been given as cm. instead of mm. The description on p. 361 is correct.

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a number of more or less fine striae running parallel to the ribs. The spine-scars are about 1 mm. in diameter (as in the type specimen) : on some of the ribs, however, they are more closely placed than in the original, so that they are deformed by mutual pressure and 9 occur in 1 cm. The ribs cross the body at a very low angle—15 degrees or less. The important feature in this specimen is the collarette which was clearly situated near one suture and had an entire margin. Herr Nindel informs me that the largest specimen of *Fayolia* known from Borna is 13 cm. long, both ends being broken off, 3·5 cm. broad, and showing 9 turns of the spiral. While the bands bear fine striae, the collarette is absent.

A further fragment of *Fayolia sterzeliana* was recorded by Professor P. Pruvost[1] from the lower Westphalian rocks near Bethune, France. The specimen shows only part of one turn of a spiral. Striations running parallel to the ribbing occur on the segments and there are two spine-scars in a distance of 3 mm.

I am also indebted to the Palaeobotanical Department of the Geological Survey of Germany for the loan of two specimens which I refer to Weiss's species. One is from the Middle Westphalian of a boring at Szyglowitz (VII), Prussia, and is identified by the angle formed by the ribs (about 15 degrees) and by the size of the spine-scars (about 1·0 mm. in diameter). Striations are borne both parallel and oblique to the ribbing. Hitherto *F. sterzeliana* has been found in the lower Westphalian only.

The other specimen is from the Lower Westphalian of Karsten Zentrumgrube near Beuthen, Upper Silesia. This is fairly well preserved, compressed, and with a chitinous surface. It is figured on Plate IV at fig. 4. The tapered end is probably part of the pedicle. The specimen is 11·5 cm. long by 2·0 cm. wide and the ribs are from 7 to 9 mm. apart, crossing the body at an angle of from 15 to 20 degrees. Although the collarette is obscure, the spine-scars are clearly seen : they measure 1 mm. in diameter and eight or nine occupy the space of 1 cm. On one segment only striations occur parallel to the ribbing, but they appear to be due to crushing in fossilisation.

Dr. V. Susta[2] has recently figured and described the first known specimen of *Fayolia* (*F. sterzeliana* Weiss) from the Westphalian of Czechoslovakia. The specimen is incomplete and curved. It measures about 7 cm. in length by 2·5 cm. in width. Six ribs are shown, crossing the body at a low angle (about 15 degrees). The segments average 11 mm. or so in width and the collarette, which has an entire margin, is near one suture. The spine-scars are very

[1] *Ann. de la société géologique du Nord*, vol. li, 1926, pl. vii, fig. 3, p. 148.

[2] Susta, V., Stratigrafie Ostravsko-Karvinske Kamenouhelne oblasti ve Svetle Paleontologie, *Kamenouhelne doly Ostravsko-Karvinskeho Reviru*, Svaek I, 1928, xvii, fig. I, p. 414.

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well preserved and are slightly larger than in the type specimen of *F. sterzeliana*, about eight occurring in a space of 2 cm. In the type ten scars occur in 17·5 mm.

Fayolia randalli and *F. major* (Newberry)

Pl. II, fig. 1; Pl. IV, fig. 6.

The specimens of *Fayolia* collected from the Chemung Group of North America and described in 1885 by J. S. Newberry[1] were then stated to be preserved in the School of Mines, Columbia College. The Newberry Collection was transferred to and is now in the New York Botanical Garden, Bronx Park, New York City. The bulk of the material representing American forms of *Fayolia* is in the U. S. National Museum, Washington. It has not been possible to see these specimens, but I have examined others obtained by the same collector (Randall) from the same beds and preserved in the New York State Museum. Dr. R. Rudemann kindly forwarded some 20 to 30 examples which are included in the Hall Collection of that Museum. It should here be pointed out that the horizon from which these specimens came was given by Newberry as Upper Devonian (Chemung Group), and that all subsequent writers have repeated this. Miss W. Goldring, of the New York State Museum, however, informs me that the Chemung Group in Newberry's time included much more than the Chemung Group of to-day, and that, while much work remains to be done on this Group, both in New York State and Pennsylvania, the horizon of the upper beds (from which Newberry's specimens came) is lowest Mississippian, i.e., *Lower Carboniferous*. The question of the horizon is dealt with more fully under *F. crenulata* (below).

The specimens occur as moulds and casts in the coarse sandstone and the finer markings have been lost. It may be said at once that there can be no doubt that *F. randalli* and *F. major* represent a single species and should be united under the name *F. randalli*. The only material difference between them is that of size, and these organisms are now known to have varied very considerably in this respect. Newberry (*loc. cit.*) distinguished *F. randalli* from *F. major* ' by its small size, its somewhat curved or sinuous form,[2] and the closer approximation of the raised ridges, which are also more flattened and relatively broader.'[3]

The best specimen from Warren in this collection (Plate IV, fig. 6), is elliptical, the shorter axis measuring 2 cm. and the longer 2·4 cm., while the fossil is just over 9 cm. long. As is usual in these

[1] Newberry, J. S., *Ann. New York Acad. Sci.*, vol. iii, 1885, pp. 219-20, pl. xviii, figs. 1-3.

[2] The ' curved or sinuous form ' is accidental.

[3] These features merely represent differences in the size of the parts, corresponding to differences in the size of the organisms. The differences in the closeness of the ridges and in their breadth is very considerable even within the original species *F. randalli*. This will be seen by comparing the two examples figured on Plate IV, fig. 6, and Plate II, fig. 1.

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organisms, the beak is not preserved, though part of the more resistant pedicle is shown. This is twisted on its axis as in *Palaeoxyris*. The ribs are separated by about 4 mm. and cross the body at an angle of 15 degrees. No less than 15 segments are shown. Average specimens of the species measure 7 or 8 cm. in length by 1·3 to 2·0 cm. in diameter, but the larger example referred to *F. major* by Newberry was 17 cm. long (and incomplete) and 2·5 cm. in diameter. The angle at which the ribs cross the body is the same in both the large and the small specimens, and there are obvious transitions between the two in every respect.

Fayolia crenulata Moysey

Pl. II, fig. 2; Pl. IV, fig. 5.

On Plate IV, fig. 5 is figured an American specimen[1] which I identify as *F. crenulata*, a species which has hitherto been known from the Coal Measures of England, where it was represented by two specimens only. Although the fossil is smaller than Moysey's types, it agrees with them in all essentials.

The chief diagnostic character consists in the clearly dentate collarette (compare *F. crenulata* figured on Plate II, fig. 2). Whereas the type specimens attain a diameter of 5·6 cm., the present example, representing a flattened cast, measures 2·1 cm. in the longer and 1·2 cm. in the shorter axis (i.e., the organism was originally about 1·6 cm. across). Again, whereas the collarettes of the type specimens were about 2 cm. apart, those of the present example were only 1·2 cm. apart. The ribs cross the body at an angle of about 30 degrees, as against about 15 degrees in the larger examples, and, while the spine-scars are very clearly shown in Moysey's fossils, they are small and scarcely visible in the present specimen. This, however, is not merely due to their smaller size: the British specimens are preserved in ironstone, showing the minutest details, while the American specimen is preserved in a sandy shale. There are no

[1] With regard to the probable horizon of this specimen (and of the Warren specimens of *Fayolia* noted above), I am indebted to Miss Winifred Goldring of the New York State Museum, University of the State of New York, for the following observations which have been made by Professor Chadwick and Dr. Butts. Professor Chadwick observes that the beds at Warren from which the specimens of *Spiraxis* (*Fayolia*) were obtained are above the true Chemung and probably Bradfordian (Mississippian or Lower Carboniferous) and that dark shales occur in bands in the lighter sandstone, so that the specimen referred to *F. crenulata* (which was unlabelled) could well have come from there. Dr. Butts, of the U. S. Geological Survey at Washington, states that *Spiraxis* has been found in two quarries within 4 miles N.W. of Warren and that these are in the Salamanca conglomerate, the middle of the Conewango Formation, which is lowest Mississippian (Bradfordian) in age. The true Chemung does not occur here. Thus, according to both Professor Chadwick and Dr. Butts the specimens here mentioned from Warren, U.S.A., are Carboniferous and very probably *Lower Carboniferous*. Previous authors, following Newberry, have always described the specimens as coming from Upper Devonian rocks, and this was accepted by the writer (*op. cit.*, 1928, pp. 325, 365). The earliest known example of *Fayolia* is therefore Stanier's *Spiraxis interstrialis* which came from the Upper Devonian of Belgium. All other known specimens of the genus are of Carboniferous (chiefly Coal Measures) or Permian age.

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striations on the segments. It is noteworthy that the size of the crenulations is fairly constant; these were about 4 mm. across in Moysey's types, while in the present specimen they are about 3 mm. across.

ADDITIONAL RECORDS OF *FAYOLIA*

F. sterzeliana Weiss

horizon : above No. 13 Seam (lower Westphalian).
locality : Fosse No. 11, Noeux, near Bethune, France (recorded by P. Pruvost).

horizon : about Middle Westphalian.
locality : Boring at Szgylowitz (VII), Prussia.
collection : Palaeobotanical Department, Geological Survey, Berlin.

horizon : Lower Westphalian (A of the Heerlen Congress Classification).
locality : Karsten Zentrumgrube near Beuthen, Upper Silesia.
collection : Palaeobotanical Department, Geological Survey, Berlin.

horizon : Westphalian Series.
locality : Czechoslovakia.
collection : V. Susta.

F. crenulata Moysey

horizon : probably Lower Carboniferous.
locality : probably Warren, Pennsylvania, U.S.A.

cf. Fayolia sp.

horizon : No. 2 Llantwit Seam (Radstockian Series).
locality : Glynogwar, Graiglas, Glamorganshire. (recorded by D. Davies, 'Correlation and Palaeontology of the Coal Measures of East Glamorganshire,' *Phil. Trans. Roy. Soc. Lond.*, 1928, Ser. B, vol. 217, p. 128).

IV. The Genus *VETACAPSULA*

I strongly suspect that under the designation *Vetacapsula* have been included two distinct generic forms, though for the present it will suffice to call attention to the facts. *V. cooperi* Mackie, the first species to be described, has a strong longitudinal ridge running down both beak and body (and observable, though less clearly, in the pedicle—see Plate II, fig. 7). The late Dr. L. Moysey carefully developed an apparently deformed example[1] of this species and found that the ridge was due to the original presence of a distinct flange, which, on splitting the rock in the ordinary way, became torn off. Such ridges are entirely absent from specimens of *Palaeoxyris* and *Fayolia*, but they occur on four species of *Vetacapsula*—*V. cooperi* Mackie, *V. moyseyi* Crookall, *V. johnsoni* (Kidston) and *V. minima* Moysey. On the other hand, three recently described, *V. kidstoni* Crookall (of which several examples are now known), *V. czernyshevi* Chabacov, and *V. hemingwayi* (described below—see Plate II, fig. 8) show no sign of such a ridge, and this is accompanied by a lack of longitudinal symmetry, whereas in the *V. cooperi* group the two longitudinal halves are very symmetrical. It may be

[1] The example referred to is preserved in the Museum of Practical Geology.

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found necessary later to separate the non-ridged and non-symmetrical forms from *Vetacapsula*, as they evidently represent different types of construction.

Since the appearance of my revision of this genus, I learn from Dr. W. J. Jongmans that a few specimens of *Vetacapsula* have been found in the Coal Measures of Holland. Details as to these specimens are not yet published, and the examples have been handed over to Professor Pruvost of Lille for investigation. Professor Pruvost informs me (*in litt.*) that they include *V. cooperi*. While the fossils are rare in Holland, as elsewhere, continued work shows that they were of wide distribution in Carboniferous times.

Vetacapsula moyseyi Crookall

A specimen of *V. moyseyi* from the Yorkian Series of Coalbrookdale (Collection of the Museum of Practical Geology, No. 14419) is typical of the larger form of the species, and is beautifully preserved in an ironstone nodule. The body is broader than long (5·6 cm. broad by about 4·8 cm. long), the shape of a conventional heart inverted. The pedicle expands suddenly into the body, forming a 'shoulder.' There are about 16 ribs across the widest part of the body, following the contour of the margins, and up to 3 mm. apart. The total length of the specimen, as preserved, is 11 cm., but the beak and pedicle are both incomplete. There is a strong central ridge down the beak, body and pedicle, and below the middle of the body is the usual deformed region. Striae are absent from the bands.

Vetacapsula kidstoni Crookall

No less than five further examples of this species have been collected by Mr. W. D. Ware from the South Wales coalfield. The length of the body varies from 6 to 10 mm. and the breadth from 3 to 5 mm. As in other species, we have to note a greater variation in the size of the organisms than was previously realised.

Vetacapsula hemingwayi n. sp.

Pl. II, fig. 8.

In 1910, Moysey[1] compared his species *V. minima* with a specimen collected by Mr. W. Hemingway from below the Haigh Moor Coal (Yorkian Series) at Brightside, Sheffield, observing that it was in the Kidston Collection. The specimen, figured on Plate II, fig. 8, is now in the collection of the Palaeontological Department, Museum of Practical Geology (No. 30,254).[2] Moysey appeared to be uncertain as to whether it should be referred to *Palaeoxyris* or to *Vetacapsula*, though he concluded, 'The specimen had better be included under *Vetacapsula*.' The feature which raised doubts in Moysey's mind was the slight tendency to a spiral arrangement in the ribbing which,

[1] Moysey, L., *Quart. Journ. Geol. Soc.*, vol. lxi, 1910, p. 336.

[2] This is the specimen referred to by the writer in 1928 (*op. cit.*, p. 96). It could not then be traced.

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however, he suggested might be due to an accident in fossilisation, Kidston also seemed to have been uncertain as to the correct generic determination, as he labelled the specimen 'Referred to as *Vetacapsula*.'

There is no doubt that this is an example of *Vetacapsula*. The writer[1] has already observed that a slight twist in the ribbing is sometimes, though not invariably, present on the body (only) of *Vetacapsula johnsoni* (Kidston), as well as on the single known example of the Russian species *V. czernyshevi* Chabacov. Kidston[2] originally included *V. johnsoni* in *Palaeoxyris*, but he had then seen one specimen only and it bore slightly twisted ribbing on the body. I regard the occasional presence of this feature in *Vetacapsula* as due to pressure. A little below the centre of all specimens there is an enlarged region which must represent the site of an essential organic structure. Specimens showing twists in the ribs often also have this enlargement exceptionally strongly developed, and the central ridge absent.

Previous workers do not appear to have always realised the essential distinctions between *Palaeoxyris* and *Vetacapsula*, no doubt owing to the very limited number of fossils available for examination : their one criterion consisted in the direction of the ribbing *on the body* (spiral in *Palaeoxyris*, parallel in *Vetacapsula*). The writer has shown, however, that while twisted ribbing invariably occurs on the body of *Palaeoxyris*, it may very occasionally be simulated in *Vetacapsula* as the result of accident in fossilisation and especially owing to the presence of an exceptionally high raised region slightly below the centre. Such twisted ribbing on the body of species of *Vetacapsula* occurs locally only and is not found in all examples of a species. If, on the other hand, the ribbing *on the pedicle* be examined, it will be found to be always spiral in *Palaeoxyris* and parallel in *Vetacapsula*. As a result of a careful comparison of numerous specimens, the writer has also shown that examples of *Vetacapsula* are usually more broadly fusiform than those of *Palaeoxyris*, and the segments generally markedly narrower. There is also in *Vetacapsula*, as at present understood, a tendency to non-symmetry in the longitudinal direction in those species where a central longitudinal ridge is absent. These features are all observable in the present specimen : the ribs in the pedicle are parallel, there is no central ridge and the fossil is non-symmetrical. The two genera, though related, are actually quite distinct, a fact which is emphasised by their distribution in geological time.

Mr. Hemingway's specimen does not agree with any known species of *Vetacapsula*, and I here describe it as *V. hemingwayi* n. sp. The fusiform body is about 14 mm. long by 8 mm. broad at the widest point. The ribs on the body are about 1 mm. apart and slightly twisted, but those on the pedicle are seen, with the aid of a lens, to

[1] Crookall, R., *op. cit.*, 1928, p. 88.
[2] Kidston, R., *Proc. Roy. Phys. Soc. Edin.*, vol. ix, 1886, p. 63, pl. I, fig. 6.

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be parallel. The beak is not preserved. There are no striae on the segments between the ribs. The specimen is larger than either *V. kidstoni* or *V. minima* (which are ·3-·6 and ·5 cm. broad respectively), and the segments are wider (·5 mm. in *V. kidstoni*: ·25 mm. in *V. minima*). In *V. kidstoni*, where there is no median ridge, the specimens are non-symmetrical (as in *V. hemingwayi*), but in *V. minima* the median ridge is strong and the organism longitudinally symmetrical. *V. hemingwayi* differs from *V. czernyshevi* Chabacov in several important particulars. The latter is much narrower in proportion to its length, the ribs are more numerous and the segments little more than half as broad.

Diagnosis of *Vetacapsula hemingwayi* n. sp.

Body broadly fusiform, 14 mm. long by 8 mm. broad, ribs about 1 mm. apart and taking a slightly twisted course on the body, though parallel in the pedicle. Beak absent.

Vetacapsula cooperi Mackie

Pl. II, fig. 7.

On Plate II, fig. 7, is figured one of the best examples of the genus known.[1] In these organisms the beak is almost invariably badly preserved, though both the body and the pedicle may be well shown. The present instance, however, shows the sharply pointed beak, about 4 cm. in length. The body and pedicle are in a perfect state of preservation. In the counterpart of this specimen (Museum of Practical Geology, No. 47923) the beak is missing. The longitudinal central ridge, which is a common feature in the larger species of *Vetacapsula*, is seen throughout the specimen.

ADDITIONAL RECORDS OF *VETACAPSULA*

V. cooperi Mackie

horizon: about 5 feet above Low Bottom or Blindstone Coal (Yorkian Series).
locality: Heasandford Brick Quarry, Burnley, Lancashire (collection of W. Barker, Burnley).
horizon: Coal Measures.
locality: Belgium (P. Pruvost).
horizon: Coal Measures.
locality: Limberg, Holland (W. J. Jongmans).

V. moyseyi Crookall

horizon: Yorkian Series.
locality: Coalbrookdale (collection of Museum of Practical Geology, No. 14419).

V. kidstoni Crookall

horizon: above first marine band (390 yds. from surface, 220 yds. below No. 2 Rhondda Seam).
locality: Cefn Coed Sinking, near Swansea (collected by W. D. Ware: collection of Museum of Practical Geology).

[1]The counterpart of this specimen (No. 47923) was figured by the writer (*op. cit.*, 1928, pl. 1, fig. 4).

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horizon: at depth of 729 yds. (Yorkian Series).
locality: ditto (Museum of Practical Geology, Nos. R.C. 1206-9).

V. hemingwayi n. sp.

horizon: Rock beneath Haigh Moor Coal (Yorkian Series).
locality: Brightside, near Sheffield (collected by W. Hemingway; collection: Museum of Practical Geology, No. 30,254).

V. johnsoni (Kidston)

horizon: ' Coal Measures ' (? Yorkian Series).
locality: Deepfields, South Staffordshire (Department of Geology, University of Birmingham).
horizon: at depth of 575 yds. (Yorkian Series).
locality: Cefn Coed Sinking, Swansea (Museum of Practical Geology, Nos. R.C. 1050, 1051).

V. cf. johnsoni (Kidston)

horizon: Upper Four-foot Seam (Yorkian Series).
locality: Nantgwyn Colliery, Penycraig, Glamorganshire (recorded by D. Davies, ' Correlation and Palaeontology of the Coal Measures in East Glamorganshire,' *Phil. Trans. Roy. Soc. Lond.*, ser. B, vol. 217, 1928, p. 129).

V.—General Distribution of Genera

Era	Epoch	*Vetacapsula*	*Palaeoxyris*	*Fayolia*	*Scapellites*
MESOZOIC	Cretaceous	—	Britain Germany ? U.S.A.	—*	—
	Jurassic	—	Korea	—	—
	Triassic	—	France Germany New South Wales	—	—
	(Lower) Permian	—	—	Germany	—
PALAEOZOIC	(Upper) Carboniferous	Britain Holland Russia	Britain Belgium France Holland Germany Czecho-slovakia U.S.A.	Britain France Germany Czecho-Slovakia U.S.A.	France
	(Lower) Carboniferous	—	—	U.S.A.	—
	(Upper) Devonian	—	—	Belgium	—

**Spiraxis bivalvis* Ward, from the Upper Cretaceous of U.S.A., has been compared with *Fayolia*, but the specimen is too imperfect to be referred to that genus and the absence of the fossils from rocks newer than the Lower Permian makes it practically certain that there is no relationship between the two.

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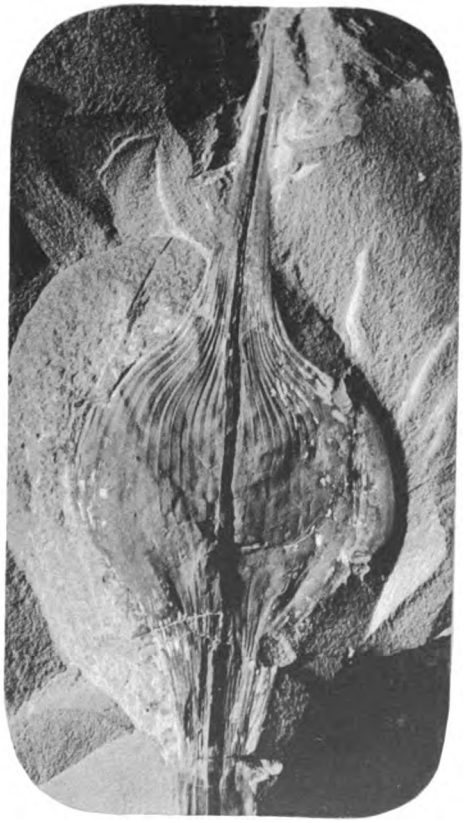
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FAYOLIA, VETACAPSULA, Etc.

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Explanation of Plates II to V

Plate II

Fig. 1.—*Fayolia randalli* (Newberry) × 1.
Hor. Chemung Group (Lower Carboniferous).
Loc. Warren, Pennsylvania, U.S.A.
Collection: Hall Collection, New York State Museum, Albany, U.S.A.

Fig. 2. *Fayolia crenulata* Moysey × 1.
Hor. Top Hard Coal (Yorkian Series).
Loc. Shipley Manor Claypit, Ilkeston, Derbyshire.
Collected: L. Moysey.
Collection: Museum of Practical Geology, No. 11,134.

Fig. 3. *Palaeoxyris prendeli* Lesqx. × $\frac{6}{5}$.
Hor. Yorkian Series (very probably Ten-foot Ironstone Measures).
Loc. South Staffordshire.
Collection: Royal Scottish Museum, Edinburgh, No. 1911.8.3.

Fig. 4. *Palaeoxyris pringlei* Crookall × 1.
Hor. at approximately 52''' 3' 6' in the Barren Red Measures.
Loc. Barony Pit Sinking, 1¼ miles west of Auchinleck, Ayrshire.
Collected by D. Tait.
Collection: Geological Survey, Scottish Office, No. T. 4014 B.

Fig. 5. *Palaeoxyris carbonaria* Schimper forma α × 1.
Hor. Thick Coal (Yorkian Series).
Loc. Coseley, Dudley, Staffordshire.
Collection: Museum of Practical Geology, No. 30,253.

Fig. 6. *Palaeoxyris carbonaria* Schimper forma typica × 1.
Hor. Ten-foot Ironstone Measures (Yorkian Series).
Loc. Coseley, near Dudley.
Collected: W. Madeley.
Collection: Museum of Practical Geology, No. 12,602.

Fig. 7. *Vetacapsula cooperi* Mackie × 1.
Hor. Furnace Coal (Yorkian Series).
Loc. Cossall Claypit, Nottinghamshire.
Collected: L. Moysey.
Collection: Museum of Practical Geology, No. 47,922.

Fig. 8. *Vetacapsula hemingwayi* n.sp. × 1½.
Hor. Rock beneath Haigh Moor Coal (Yorkian Series).
Loc. Brightside, near Sheffield.
Collected by W. Hemingway.
Collection: Museum of Practical Geology, No. 30,254.

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PLATE III

Fig. 1. *Fayolia eltringhami* n.sp. × 1.
Hor. Crow Coal (Yorkian Series).
Loc. Phoenix Brickyard, Crawcrook, Durham.
Collected by W. Eltringham (the specimen is to be presented to the Hancock Museum, Newcastle-upon-Tyne).

Fig. 2. a, b. *Fayolia cambriensis* n.sp. × 1 (specimen and counterpart).
Hor. Mynyddislwyn Seam (Radstockian Series).
Loc. Gwernau Level (Mr. Walker's), ¾ mile S.E. of Maes-y-cwmmer, and ½ mile E. of the Boot Hotel, Aberdare, Mon.
Collected: J. Pringle.
Collection: Museum of Practical Geology, No. 48521.

Fig. 3. *Palaeoxyris jugleri* (Ett.) × 1.
Hor. Wealden.
Loc. Egestorf, Deister, Germany.
Collected and photographed by R. Florin
(two specimens are shown, converging by their beaks to a common centre).

Fig. 4. *Palaeoxyris jugleri* (Ett.) × 1½.
Hor. Fairlight Clays (Wealden).
Loc. Ecclesbourne, near Hastings, England.
Collection: British Museum (Natural History), No. V. 3171.

Fig. 5. *Palaeoxyris münsteri* (Presl) × 1.
Hor. Lower Lias.
Loc. Scania (Photograph by R. Florin).

Fig. 6. *Palaeoxyris münsteri* (Presl) × 1.
Hor. Lower Lias.
Loc. Scania.
Photograph by R. Florin of Nathort's specimen (which he compared with *P. quenstedti* (Schimper)).

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a

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FAYOLIA AND PALAEOXYRIS.

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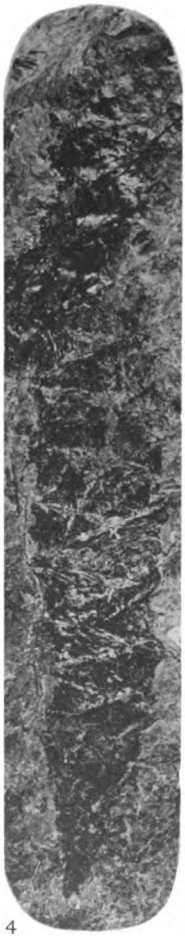
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FAYOLIA AND PALAEOXYRIS.

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PLATE IV

Fig. 1. *Palaeoxyris bohemica* n. sp. × 1.
Hor. (?Lower) Carboniferous.
Loc. Bohemia.
Collection: British Museum (Natural History), No. V. 3596 a.

Fig. 2. *Palaeoxyris bohemica* n. sp. × 1.
Hor. (? Lower) Carboniferous.
Loc. Bohemia.
Collection: British Museum (Natural History), No. V. 3596 c.

Fig. 3. ? *Palaeoxyris* sp. × 1.
Hor. Middle Cretaceous.
Loc. Kansas, U.S.A.
Collected by E. W. Berry, Johns Hopkins University, Baltimore.

Fig. 4. *Fayolia sterzeliana* Weiss × 1.
Hor. Lower Westphalian ('A' of the Heerlen Congress Classification).
Loc. Karsten Zentrumgrube, near Beuthen, Upper Silesia.
Collection: Palaeobotanical Department, Geological Survey, Berlin. (Spine-scars may be seen at various points by the aid of a lens.)

Fig. 5. *Fayolia crenulata* Moysey × 1.
Hor. Unknown.
Loc. Unknown (U.S.A.).
Collection: Hall Collection, New York State Museum, Albany, U.S.A.

Fig. 6. *Fayolia randalli* (Newberry) × $\frac{3}{5}$.
Hor. Chemung Group (Lower Carboniferous).
Loc. Warren, Pennsylvania, U.S.A.
Collection: Hall Collection, New York State Museum, Albany, U.S.A.

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PLATE V

Fig. 1. *Scapellites cottoni* Pruvost × 1.

Hor. 1150 metres (Coal Measures).

Loc. Puits No. 10 (Grisoeuil) de la Compagnie de Charbonages Belges.

Type specimen, collected by A. Renier: photograph by P. Pruvost.

Collection: Service géol. de Belgique.

Figs. 2, 3. *Scapellites cottoni* Pruvost × 3.

Hor. as above.

Loc. as above.

Photographs by P. Pruvost.

Fig. 2 shows two normal capsules.

Fig. 3 shows a capsule in which the component filaments have become dissociated.

Fig. 4. *Palaeoxyris regularis* Brongt. × 1.

Hor. Lower Trias.

Loc. Sultz-les-Bains, France.

Photograph of Brongniart's drawing (fig. 'a'—fig. 'b,' regarded by Brongniart as representing a scale of *Palaeoxyris*, is omitted as the fossil bears no relation to that organism).

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SCAPELLITES AND PALAEOXYRIS

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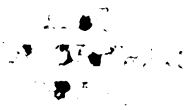

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III.—ON THE ORIGIN OF THE ST. BEES-WHITEHAVEN GAP

BY

BERNARD SMITH M.A., SC.D.

Text-figure 1

Between St. Bees and Whitehaven on the West Cumberland coast there is a remarkable trough-like and crescent-shaped valley, 5 miles in length, which is traversed throughout by the London, Midland and Scottish Railway, obviating a difficult passage round the seaward face of St. Bees Head or a wide detour inland. The origin of this striking gap, open to the sea at each end, has been a constant source of speculation. An attempt is now made to explain the initiation and subsequent development of the valley.

In the Whitehaven district the New Red Rocks lie unconformably upon Carboniferous Rocks which form undulating country of plateau-like moorlands falling from an elevation of 700-800 ft. 5 miles north-east of Whitehaven to about 300-400 ft. near Whitehaven and Cleator. Between Arlecdon and Dean Moor (Fig. 1). these uplands form a breached escarpment facing eastward.

Apart from isolated outliers the main outcrop of the New Red Rocks forms a definite escarpment about 6 miles in length, trending north-west and south-east, from near Barrowmouth on the sea-coast south of Whitehaven to Egremont on the Riven Ehen, and thence to the Kirk Beck. Usually it rises about 100 ft. above the sloping plateau formed by the Carboniferous Rocks. Its average height is about 400 ft. above Ordnance Datum, although in places this is somewhat exceeded.

Near the coast the escarpment is breached by the St. Bees-Whitehaven valley and about three miles farther south-east by the valley of the River Ehen. The latter flows out of Ennerdale Water and is joined by the River Keekle, with north to south course, at Cleator.

Of these valleys the former is by far the most imposing. Its northern part, 3 miles in length, trends S.15°E. and is cut in Coal Measures in which it forms a trough about 200 ft. in depth. Its western wall near Whitehaven, where the Whitehaven Sandstone caps the Coal Measures, is steepest and highest. The ground rises more gently to greater elevations some distance from the immediate slopes on both sides of the valley.

The nearly flat floor of this section of the valley varies from ¼ to ½ mile in width and rises gently from mean tide level to 50 ft. above at a distance of two miles from the sea.[1] About ¼ mile farther south it attains its greatest height, approximately 78 ft. Here Coal Measures appear at the surface and the railway passes

[1] An important fault traverses this part of the valley longitudinally.

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through a cutting (at Mirehouse) about 30 ft. in depth. This ridge of solid rock separates the bottom of the valley into two portions. To the north land drainage enters the sea at Whitehaven, whilst to the south it flows out at St. Bees, both streams being named ' Pow Beck.'

South of the ridge the surface level of the floor descends rapidly to less than 50 ft. O.D. at the head of a long alluvial and peaty tract that extends as far as St. Bees.

This southern part of the valley, 2 miles in length, trends south-westward and is cut almost entirely in the St. Bees Sandstone, appearing as a deep U-shaped, but flat-bottomed, gorge about 300 ft. in depth and ¼ mile in width at its base. The little Pow Beck, which, with small tributaries, drains this tract, is an obvious misfit and has found some difficulty in entering the sea owing to a bar of glacial material at the mouth of the valley.

At the bend in the valley the eastern wall is lower than usual and falls away somewhat to the east, offering a fairly stiff gradient to the Whitehaven and Cleator Moor Railway.

Thus the St. Bees-Whitehaven valley emphatically cuts off the bold headland of St. Bees from the mainland. If the country were submerged about 80 ft. the sea would flow through as a strait, and the headland would then justify its local appellation of ' Preston Isle.'

The floor of the valley is filled with boulder-clay which descends chiefly from the higher ground to the east and underlies the alluvial deposits. On the low ridge in the valley bottom Glacial drift is thin or absent.

Theories as to origin.—In endeavouring to account for the gap several observers[1] have concluded that glaciation played a part in its formation. Glaciation, however, could not have been responsible for the whole effect; pre-Glacial physiographic agents must have played the primary and initial role. The valley obviously was not formed as a great ' in-and-out ' marginal drainage channel on the flank of the Irish Sea Ice. It is far too large. Again, its gradient does not descend from north to south but rises first to the ridge or col in the valley bottom, and Glacial drift covers most of its floor. It is, however, a ' through valley ' suggestive of the erosive effects of a great mass of ice driving down it from north to south; if so, there must have been some guiding grooves for the ice to have worked upon.

If we dismiss the idea of a marginal channel drainage, there remain two possible ways in which the valley may have first originated:—

(1) A river flowed from the north parallel to the old coast, but outside the present coast-line for the most part, the valley that

[1] See for example, the Rev. Caesar Caine, ' Geological and Historical Notes on St. Bees Valley,' *Whitehaven News*, April 6, 1916.

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remains being beheaded by marine erosion. Such a river would be similar to the supposed 'Solent River' on the South Coast.

The Derwent, now entering the sea at Workington, was considered, but rejected because (i) there appears no adequate reason why this river, after flowing westward, should turn directly southward, (ii) the solid ridge crossing the valley floor (even after glaciation) offers objections that appear to be insuperable.

(2) The true head of the southern part of the valley lies inland in a direction north-east of the bend in the valley and facing the St. Bees Sandstone Escarpment, whilst the northern end of the valley owes its existence to small local streams concentrating on what is now Whitehaven. This seems to us to be the most reasonable theory.

Pre-Glacial History.—If we take a map of the district (preferably a one-inch geological 'drift' map) and draw a straight

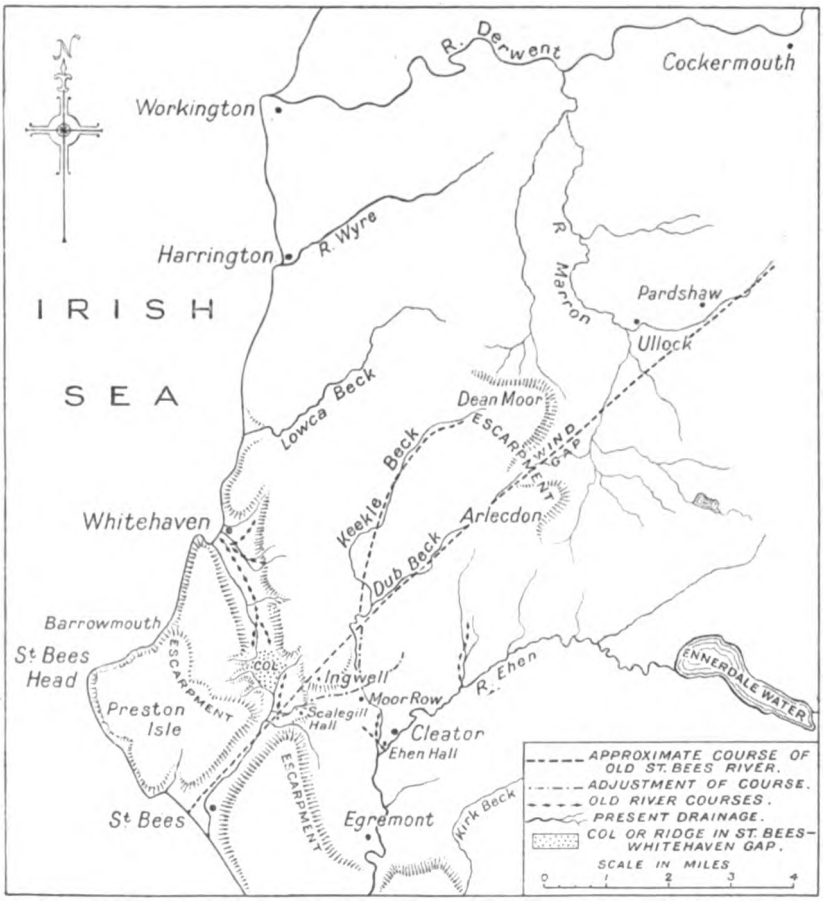

FIG. 1.—*Development of River Courses near Whitehaven.*

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line along the centre of the St. Bees valley from St. Bees, and prolong it inland, we see that it aims directly for the course of the Dub Beck, the most important tributary of the present River Keekle; and if we continue the line beyond the River Marron (Fig. 1) it follows the course of a tributary of the latter stream south of Pardshaw. It is now claimed that at the initiation of the drainage the original St. Bees River flowed south-westward from high ground east of (and with tributaries south of) Pardshaw directly to St. Bees, and subsequently the escarpments of Whitehaven Sandstone (Dean Moor-Arlecdon) and St. Bees Sandstone (Barrowmouth-Egremont) were developed by weathering, etc., the main drainage line meanwhile maintaining its course and sinking its thalweg in gorges through the growing escarpments.

At some subsequent but fairly early date the River Marron, tributary to the Derwent, captured the headwaters (the Pardshaw stream and tributaries from the south) and so beheaded the St. Bees River, leaving a wind-gap at the entrance to the gorge through the Whitehaven Sandstone north of Arlecdon.[1]

The present course of the Dub Beck follows a pre-Glacial valley evidently long established and so does that of the Keekle above its junction with the Dub Beck.

A little below the junction the Keekle now turns southward and passes Moor Row to join the River Ehen near Cleator.

Where then are we to find the old connexion with the St. Bees valley?

Although the original stream must have flowed almost direct from the site of the present Dub Beck-Keekle junction to St. Bees it is concluded that its valley in the course of time became adjusted to the geological structure, the stream then first flowing southward to the east of the St. Bees Sandstone outlier of Ingwell, and then westward, along the Coal Measures (which are faulted against Carboniferous Limestone on the south) and a certain amount of New Red Rocks, from Moor Row to Scalegill, where it turned and followed its original direction through the escarpment.

Numerous borings for iron ore and coal, through overlying Glacial deposits, show that from the bend in the St. Bees-Whitehaven valley near Scalegill a buried valley (now hanging above the bottom of the St. Bees valley) extends to beyond Moor Row—crossing the line of the present Keekle. At the lowest depth plumbed near Moor Row it is at 124-130 ft. above O.D. and connects with the buried Keekle valley to the north. A small tributary from the north-east joined this buried valley at Moor Row.

South of Moor Row the present Keekle appears to flow across a buried col (traversed by the north-north-west Crossfield Fault), south of which there was a small tributary to the Ehen. The floor of this tributary—perhaps deepened by subsequent ice erosion—is

[1] The suggestion that the old river rose beyond the present Marron, and was beheaded by the latter at an early date, is perhaps a debatable point (raised by my colleague Mr. E. E. L. Dixon), but one which in no wise affects the main thesis.

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hanging with respect to the floor of the Ehen valley near Ehen Hall. Study of the borehole records suggests that it had not captured the old St. Bees River at Moor Row in pre-Glacial times.

The bottom of the old St. Bees River fell at fairly regular grade from its truncated head north of Arlecdon to the St. Bees valley, and if this gradient had been maintained down the St. Bees valley the river would have met the coast-line at about present sea-level.

Thus we envisage a pre-Glacial river, commencing north of Arlecdon, entering the site of the present St. Bees valley near Scalegill at about 80 ft. above sea-level, and dropping to sea-level at St. Bees; and its valley would have been separated from the small valley opening northward at Whitehaven by a col, near Mirehouse, of considerable elevation.

During the Glacial period the valleys of the St. Bees River as far south as the St. Bees gap, and its tributary (now occupied by the Upper Keekle), were partially or wholly swathed in boulder-clay or fluvio-glacial deposits, but the part that runs westward from Moor Row was almost completely buried, as it lay athwart the trend of ice-movement.

On withdrawal of the ice the old drainage lines were generally picked out again from headwaters down to Moor Row, but here the post-Glacial stream crossed the above-mentioned col and roughly followed the track of the old tributary to the Ehen, which latter now flows in a glacially overdeepened valley.

The lower layers of ice driving from the north into the Whitehaven valley became concentrated and scoured out the Coal Measures and degraded the col (which separated this little valley from the St. Bees River valley and probably extended farther north than at present) down to its present level. On surmounting this obstacle it overdeepened the gorge of the old St. Bees River. At a point about 500 yds. west-south-west of Scalegill Hall its floor is now over 38 ft. below O.D., and at the mouth of the valley (St. Bees B.H. No. 1) it is at least 81 ft. below sea-level.

Glacial scouring throughout the whole length of the now fully developed Whitehaven-St. Bees gap steepened its sides and caused most of the small side valleys (either old ones or newly formed)—as well as that of the old St. Bees River east of Scalegill—to become 'hangers.' The present streams in these valleys on entering the St. Bees-Whitehaven gap now flow either to the north or south according to their position relative to the central rise in the valley floor.

Thus this extraordinary feature appears to owe its origin to glacial obstruction of part of the old St. Bees River drainage system, and to the scouring effects of ice crowding into a pre-Glacial valley opening out at Whitehaven, breaking down the division between that valley and the St. Bees River valley and both overdeepening and widening the lower end of the latter.

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IV.—A RECENT BORING AT BURNTISLAND IN THE LOWER OIL-SHALE GROUP

BY

J. K. ALLAN, M.A., B.Sc.

In the recently published 'Oil-Shales of the Lothians'[1] a short account is given of the structure and sequence in the Burntisland district. Excellent sections of the Burdiehouse Limestone are noted in the old quarries at Newbigging and Kilmundy, on the west side of the Binn of Burntisland, and in those of Dodhead and Brosyhall on the east side. The beds above the limestone, up to the horizon of the Houston Coal, are known in detail from borings and natural sections. Of the strata below the Burdiehouse Limestone, however, little information has been available, although a boring at Whinnyhall, put down in 1906, went to a depth of 140 fathoms below the limestone. Several dolerite intrusions were recorded in this bore, but no trace of the Pumpherston Shales was detected.[2]

Recently a bore for water was put down by the British Aluminium Co. at their works at Kirkton, Burntisland, and permission was kindly granted to the Survey by Mr. W. Edgar Sims, Manager, to examine the cores.

The bore starts about 40 fms. below the Burdiehouse Limestone and cuts the following 400 ft. of strata, which are poorly exposed on the coast between Colinswell and Burntisland.

	Thickness			Depth		
	Fms.	Ft.	In.	Fms.	Ft.	In.
Surface	4	1	–	4	1	–
Blaes	2	3	–	6	4	–
Sandstone	2	–	6	8	4	6
Blaes	4	3	6	13	2	–
Sandstone, brownish	4	2	–	17	4	–
Blaes, hard	6	2	–	24	–	–
Marine band	–	2	–	24	2	–
Sandstone, with kingle band ...	9	4	–	34	–	–
Limestone, shelly, sandy	–	–	3	34	–	3
Fakes and sandstone	1	4	–	35	4	3
Blackband Ironstone, poor	–	–	4	35	4	7
Blaes	–	2	2	36	–	9
Limestone, shelly	–	–	3	36	1	–
Sandstone, reddish	3	1	–	39	2	–
Limestone, grey, sandy	–	1	–	39	3	–
Blaes	–	3	–	40	–	–
Sandstone	1	–	–	41	–	–
Fakes and blaes	4	–	–	45	–	–
Limestone, shelly	–	1	–	45	1	–
Blaes, irony	–	4	–	45	5	–
Limestone, shelly	–	1	–	46	–	–
Fakes and blaes	5	5	–	51	5	–

[1] 3rd Ed. (*Mem. Geol. Surv.*), 1927, pp. 95-99.

[2] *Ibid.*, p. 96.

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	Thickness			Depth		
	Fms.	Ft.	In.	Fms.	Ft.	In.
Limestone, dark, shelly	–	1	–	52	–	–
Blaes, burnt	–	3	–	52	3	–
Whinstone	1	–	–	53	3	–
Fakes, burnt	–	3	–	54	–	–
Fakes and sandstone	2	4	–	56	4	–
Fakes	4	2	–	61	–	–
Brown Shale (poor oil-shale)	–	1	6	61	1	6
Fakes, dark, broken	–	5	6	62	1	–
Sandstone, hardened	4	3	–	66	4	–

Mr. J. Pringle has determined the fossils collected by Mr. Manson as follows :—

Lepidodendron sp. at 9 fms.

Telangium affine (*L. & H.*) at several horizons.

cf. Lithodomus carbonarius *Hind.* at 59 fms.

Orbiculoidea nitida (*Phill.*), and Lingula squamiformis *Phill.* at 52 fms.

Fish scales at 34 fms.

Orthoceras sp. and Beyrichoceratoides *cf.* truncatum (*Phill.*) in the lower 2 ft. of a thick blaes at 24 fms. 2 ft.

This occurrence of *Beyrichoceratoides* cf. *truncatum* (Phill.) is of interest, as the shells are identical with those recorded as *Glyphioceras truncatum* from the marine band in the Fordell railway-cutting, and on the shore at Seafield Cottage, St. Davids. The Fordell marine band, which was tentatively correlated with the Raeburn Shell-bed,[1] would thus appear to belong to a horizon much lower in the sequence. Considerable support is lent to this view by the fact that careful search of the beds on the shore, from Seafield Cottage down to the lavas exposed in the core of the anticline at Dalgety Bay, has failed to reveal any trace of the Burdiehouse Limestone. It is probable therefore that the blaes passed through at 24 fms. 2 ft. in the bore represent the marine band of Fordell, and may be very near the position of the Pumpherston Shell-bed of the Lothians.

[1] The Oil-Shales of the Lothians, 3rd ed. (*Mem. Geol. Surv.*), 1927, p. 99.

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VA.—MAGNETIC OBSERVATIONS ON THE SWYNNERTON DYKE

BY

A. F. HALLIMOND, M.A.

Reprinted from The Mining Magazine, *July*, 1929

Text-figures 1 to 4

Considerable interest has lately been aroused in the use of physical methods for determining the occurrence and form of rocks under cover; the question how far the instruments and methods proposed in recent years could be utilized for the precise mapping of concealed structures has for some time engaged the attention of H.M. Geological Survey. In 1927 a test traverse was made across the Swynnerton Dyke with the Eötvös torsion balance,[1] and this was followed by torsion balance surveys at Drumry[2] near Glasgow and at Portobello.[3] One of the oldest and best-known methods of geophysical prospecting depends upon the measurement of the local variation in the magnetic forces over an area. In theory this is closely linked with the gravitational method, and it is of special interest to compare the results given by the two methods over a mass of rock which differs both in density and in magnetic permeability from the surrounding material. Of late years great improvements have been made in the magnetic apparatus, so that an accurate observation can be obtained in the course of a few minutes; the present note records the result of a trial survey made during twelve days with the Schmidt vertical field-balance,[4] recently acquired by H.M. Geological Survey. The structure chosen was the southern end of the Butterton-Swynnerton Dyke in North Staffordshire.[5] The dyke forms a nearly vertical wall of nepheline-basanite intruded in the Keuper Marls; it attains a thickness of over 100 feet near Yarnfield, but is only seen to the south of this point at one locality, where it is represented by three four-foot dykes of a fine-grained chilled rock, in fairly fresh condition. The rock is strongly magnetic, being rather rich in iron ores, and it will be shown that by the field balance it could be traced with some certainty even under cover for a distance of nearly 2 miles south of Yarnfield. Beyond this the outcrop was obscured by the L.M. & S.R. Main Line (L. & N.W.R. section), which renders accurate magnetic survey impossible for a distance of at least 100 ft. on either side of the railway.

[1] Supplied by Messrs. Oertling, Ltd. See McLintock, W. F. P., and J. Phemister, *The Mining Magazine*, Dec., 1927, p. 363. 'Summary of Progress' for 1927 (*Mem. Geol. Surv.*), 1928, pt. ii, p. 1.

[2] *Trans. Roy. Soc. Edin.*, vol. lvi, pt. i, No. 7.

[3] 'Summary of Progress' for 1928 (*Mem. Geol. Surv.*), 1929, pt. ii. Contribution No. 2.

[4] This instrument was manufactured by the Askania Company, Berlin.

[5] See 'The Country between Stafford and Market Drayton' (*Mem. Geol. Surv.*), 1927.

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Apparatus.—The Schmidt vertical field balance is extremely simple, consisting of a horizontal magnetized balance-beam, which can be swung on obtuse quartz knife edges. The beam, which is placed at right angles to the magnetic meridian, and is thus subject only to the vertical component of the earth's force, is brought approximately to the horizontal position by an adjustable weight. Small changes in the vertical force cause the beam to tilt and the displacement is read upon a scale, which is reflected in a mirror attached to the beam. Copper dampers bring the beam to rest in a few seconds and readings can be obtained with certainty to 0·1 scale division. Simple though this arrangement may appear, the mathematical investigation[1] of its behaviour has been much discussed and has been the subject of numerous important corrections. Fortunately these chiefly concern the constructor; in use it is both simpler and safer to calibrate the instrument by placing it in a known magnetic field. Auxiliary magnets are provided to neutralize part of a strong magnetic anomaly so that the deflexion does not exceed the scale, and in the absence of an apparatus for producing a standard field these may be used to check the scale value, provided that their moment is verified in the laboratory from time to time. For the most accurate work a small temperature correction must be employed, and also corrections for the value of the earth's force at the time of reading. In dealing with large anomalies, like those of the dyke at outcrop, these are unimportant, but they must be considered in the case of curves such as those for the dyke under cover, where the maximum value of the anomaly may be as low as 30 gamma (the unit of magnetic force, termed gamma, is 10^{-5} C.G.S.). The instrument is mounted on a tripod and has the weight and portability of a camera; but care must be taken to avoid exposing any of the magnets to mechanical shocks or to stray magnetic fields.

Method of Survey.—In totally unknown ground observations are taken at a network of points, after which traverses may be made on selected lines to establish the nature of the outstanding magnetic features. In the present case, however, the general character of the feature to be mapped can be foretold on geological grounds; it consists of one or more walls of rock, probably of fairly uniform north-south strike and very long in comparison with their width; traverses can therefore be at once employed. Since the general direction of the outcrop is in the magnetic meridian, the northward horizontal force due to the dyke will represent a balance between the forces exerted by those portions of the dyke north and south of the point of observation; it will be small and irregular and not subject to critical variations. The vertical force, on the other hand, increases sharply as the instrument passes over the dyke, and is therefore suitable for investigating the

[1] For details see C. A. Heiland, *Geophysical Prospecting*, American Inst. of Min. and Met. Eng., 1929, pp. 261-314.

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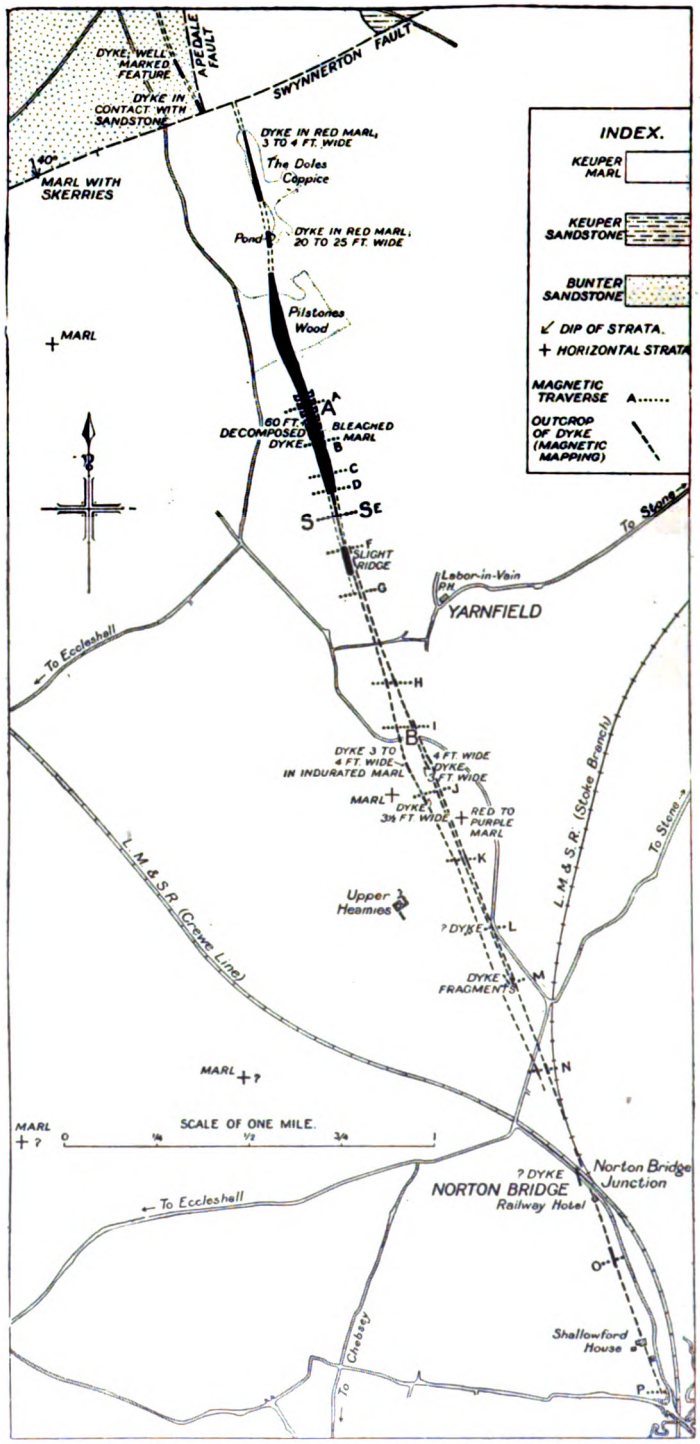

FIG. 1.—*Southern end of the Swynnerton Dyke, mapped with the vertical field-balance.*

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present structure. A number of traverse lines were chosen at right angles to the dyke and at roughly equal intervals beginning north of Yarnfield, where the dyke outcrops with a width of over 100 ft., and ceasing at the railway south of Norton Bridge; their positions are shown by broken lines on the map[1] (Fig. 1). Values of the vertical anomaly were determined at intervals of from 5 to 50 ft. along these lines and the resulting curves are shown in Figs. 3 and 4, in which the ordinates represent the scale readings of the vertical balance at the distances indicated on the horizontal scale. The curves have been placed so that the features due to the right-hand (eastern) dyke are roughly in the same vertical line.

Interpretation.—In European latitudes a mass of magnetic rock exerts its maximum vertical force at a position almost vertically above, so that even under a considerable amount of cover the position of a dyke may be inferred and mapped without special calculations. Determination of the thickness and the depth of cover involves further considerations to which it is hoped to refer in detail at a later stage. For the present purpose the dyke may be regarded as magnetized by the earth's field so that the upper surface has a south polarity. This exerts a strong positive (downward) vertical force, which quickly diminishes when the balance is no longer above the dyke. Since the balance stands about four feet above the ground it must be borne in mind that, even if the dyke is in fresh condition and at the surface, there is still four feet of cover and the anomaly does not fall to zero immediately the instrument crosses the edge of the exposure. Again, if the dyke is not quite vertical the sides also assume a weak polarity and the simple curve is rendered unsymmetrical, becoming higher over the hanging wall and steeper on the side of the footwall, as will be seen in the following example, which was chosen to illustrate the effects of dip and cover. At the top of the hill south of Yarnfield a four-foot dyke dipping about 70° W. is clearly exposed in a marl pit. A careful traverse was taken over it at about 20 ft. from the edge of the pit, with the result shown in Fig. 2. Curve II indicates the values obtained when the tripod was lowered to a height of about 2 ft. 8 in., while Curve 1 was obtained with the tripod at its usual height of 4 ft. The influence of the dip is clearly seen, though it is somewhat emphasized by the slope of the ground, which produces a similar effect.

Turning to the main traverses A to P shown by dotted lines on the map (Fig. 1), the following details may be noted. Beginning from the north the first traverse A (Fig. 3) indicates a wide dyke (about 200 ft.), with a less magnetic central portion. The latter feature is repeated in the second traverse, taken a few yards south of the quarry, where specimens of the rock were obtained. There is

[1] This sketch-map is based upon that given in 'The Country between Stafford and Market Drayton' (*Mem. Geol. Surv.*), 1927, p. 64; it covers parts of one-inch Sheet 139 and 6-in. Sheets 29 N.E., 29 S.E., and 30 N.W., 30 S.W. (Staffs.).

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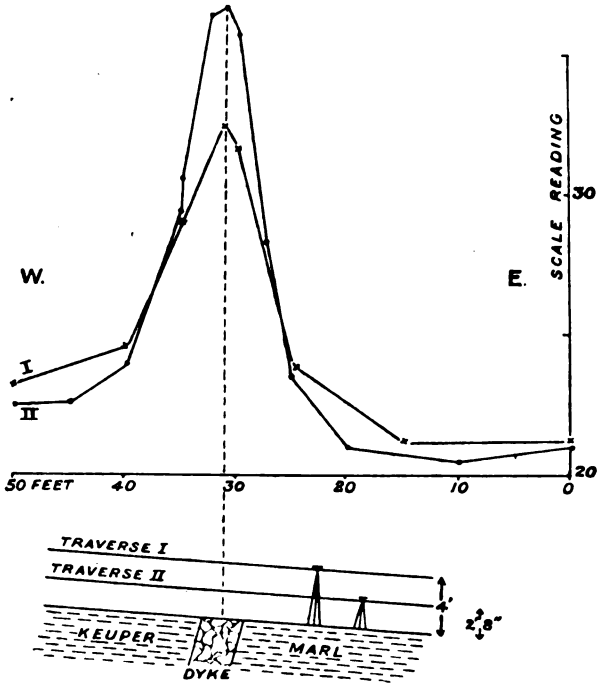

FIG. 2.—*Magnetic traverses (vertical force) across a branch of the Swynnerton Dyke with the balance at different levels. One scale division =30 gamma.*

no doubt that the lower values in the central portion of the curve are due to the nature of the rock, which proved in the micro-section to be somewhat lighter, more weathered, and poorer in iron ores than the marginal parts of the dyke. This is of some importance, because a similar curve will be shown in the later traverses to arise from two parallel dykes under cover; the choice between the alternative interpretations depends largely upon the geological evidence. In traverse C, the curve exhibits only one peak, but the anomaly is appreciable for a considerable distance on either side, in a manner consistent with the presence of a thicker body of rock below the outcrop. D is on the level ground, immediately across the point of the main ridge. The anomaly diminishes at once on either side, as required for a dyke with nearly vertical walls and very little cover; it is clear that the width of the dyke has already diminished to about 35 ft. Traverse E[1] indicates a fairly narrow dyke of about fifteen feet, under a moderate amount of cover, and dipping to the west at a high angle. This is the only point where the dyke was found to give a simple curve.

[1] This traverse is upon the same line as that made with the torsion balance in 1927 by Drs. W. F. P. McLintock and J. Phemister, *loc. cit.* It will be seen that the present measurements are in substantial agreement with the conclusion drawn from the torsion balance survey.

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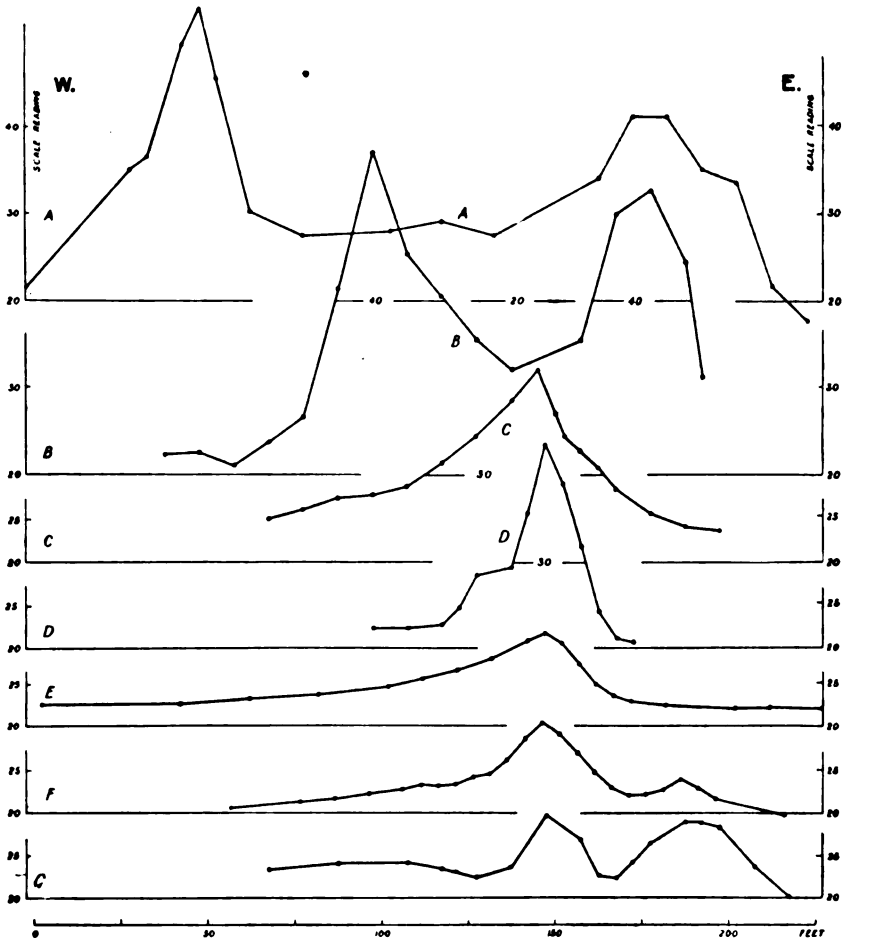

FIG. 3.—*Magnetic traverses (vertical force) across the Swynnerton Dyke. One scale division = 30 gamma.*

The next traverse, F, indicates the appearance of a second dyke which attains full development in G. Two complete peaks occur with a very low anomaly between them, a result that can only be explained by the existence of two parallel dykes with very little cover. A third dyke to the west appears faintly in F and more clearly in G. From this point onwards three dykes are indicated in nearly every traverse up to the railway (see Fig. 4).

It will be clear from the example given with the tripod at various heights that the vertical force diminishes rapidly as the amount of cover increases. This is seen on comparing traverses H and I in marshy ground near Yarnfield with traverses J and K on the hill to the south (near Upper Heamies). On the hill the dyke is exposed in three branches each about 4 ft. wide; traverses H and I in the

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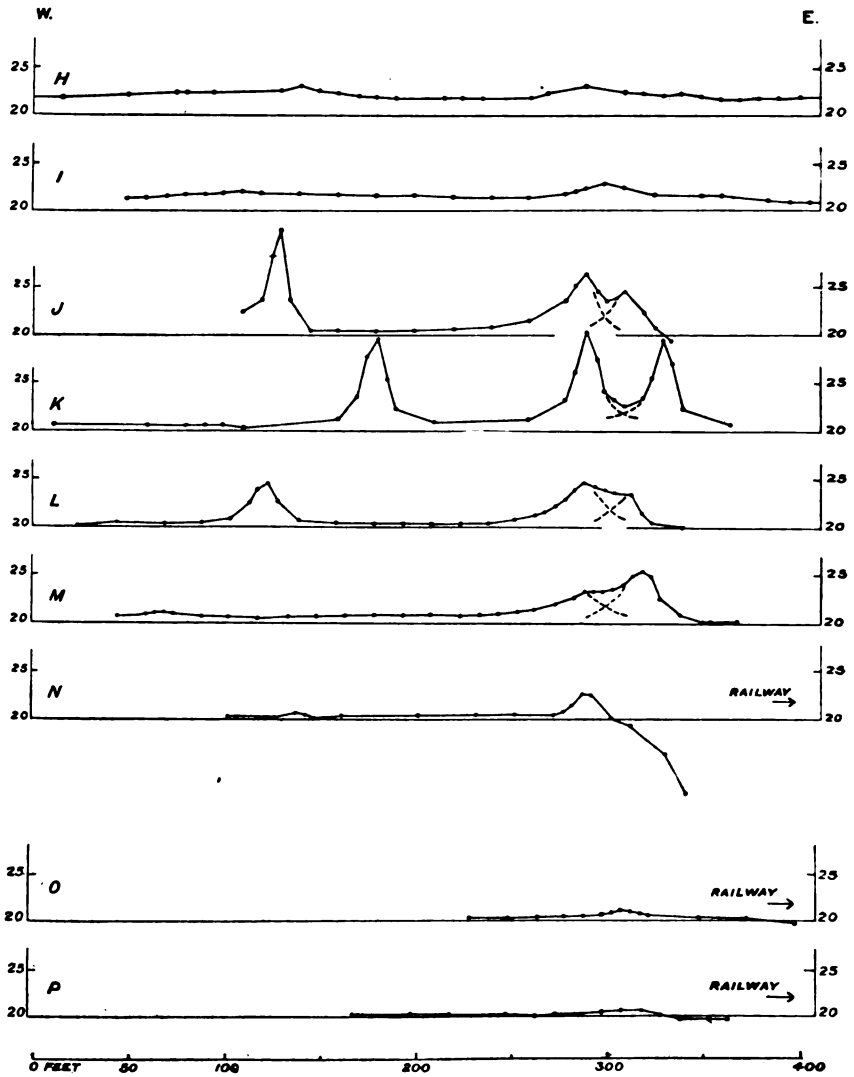

FIG. 4.—*Magnetic traverses (vertical force) across the Swynnerton Dyke. One scale division=30 gamma.*

valley show corresponding features, but the maximum amount of the anomaly is only about one-tenth of that due to the dykes at the outcrop (see traverses E, F, G, J, K) and the curves are blunted. A cover of about 40 ft. must be assumed for the western dyke in I, diminishing to 16 ft. over the eastern dyke. Traverse J, on the hill, agrees fully with the exposure near by, the blunting effect of slight cover being seen in the eastern dykes, but it is clear that the composite curve is the sum of two simple component curves (dotted lines) due to two parallel dykes and is not due to the outcrop of a wide

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dyke of variable magnetic character. In K all three dykes are apparently close to the surface, while L and M, taken toward the foot of the hill, show a certain amount of cover. Finally, the dykes approach the railway in the valley at Norton Bridge, where the eastern ends of the curves are distorted by a rapidly increasing negative force due to the railway (railings, bridges, etc.). On this account no very reliable conclusion can be drawn from the shape of the curves in N and P, but it is clear that the dyke persists as far as the cross-road south of Shallowford House, after which the outcrop again passes under the L.M. & S.R. Main Line.

The position of the dykes may be inferred from that of the maximum anomalies along the corresponding traverse, and can at once be plotted upon the traverse lines in Fig. 1. The conclusions from the magnetic survey are in full accord with the known exposures on the hill at Upper Heamies, and there is sufficient correspondence between the successive traverses to justify the construction of the heavy broken line shown in the sketch map as the southward extension of the outcrop of the dykes. It will be noticed that although the dyke could not be mapped to the south of Yarnfield at the time the geological map was under revision, there are a number of isolated occurrences of fragments, etc., which find a satisfactory explanation in the course now proved for the southern end of the Swynnerton Dyke.

Vb.—CALCULATION OF DEPTHS AND THICKNESSES FOR THE SWYNNERTON DYKE

BY

A. F. HALLIMOND, M.A.

Text-figures 5 to 8

By means of the vertical field balance the boundary of a magnetic rock under moderate cover can be traced and mapped in the manner already indicated for the Swynnerton Dyke[1]. If this is the only purpose, detailed mathematical calculations need not be made, since a characteristic change in the vertical force usually marks with sufficient accuracy the boundary of the formation; both the depth and thickness of the dyke can, however, be obtained from the Swynnerton traverses by a very simple method which will be described in the present note. Calculations of the force due to a magnetized body have commonly been made by way of the gravitational potential. This method is somewhat tedious and in most cases of geological interest the same result can be obtained more readily by direct calculation of the magnetic force, as in the present example, in which the subject is approached from the standpoint adopted by Rücker.[2]

[1] See the preceding contribution, in which will be found Figs. 1-4.

[2] *Phil. Trans. Roy. Soc.*, 1896, vol. 188A, pp. 639 *et seq.*

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The theoretical treatment is based upon certain assumptions which are made equally in the potential theory. These have been summarized by Haalck (Magnetischen Verfahren, 1927, p. 48), the most important being that the rock is uniformly magnetized throughout its mass.

Figure 5 (*cf.* Fig. 2) shows the magnetization in the earth's field of a dyke of magnetic rock with (magnetic) N.-S. strike and dipping

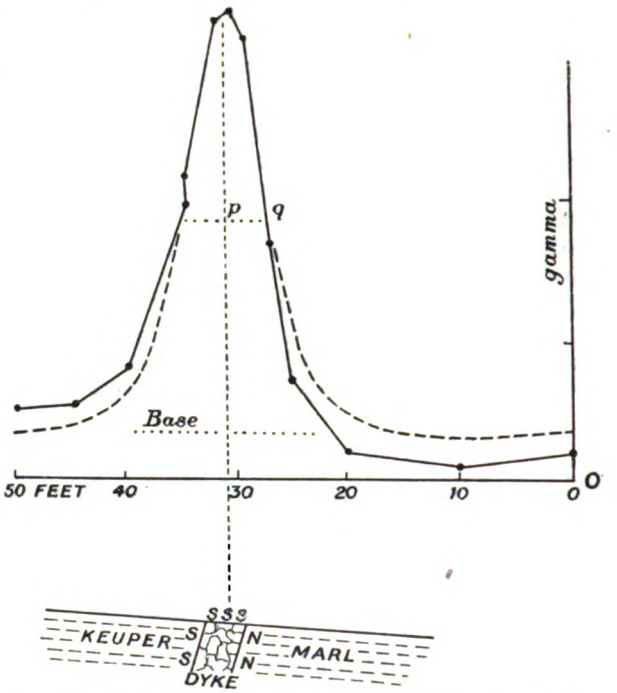

FIG. 5.—*Magnetization of an inclined dyke in the earth's field: equivalent symmetrical profile (broken line).*

steeply to the west; the vertical force profile, for a traverse at right angles to the dyke, represents the type of curve at present under consideration. This profile is really the sum of three simple curves, corresponding respectively to the top and the two sides of the dyke. The top and the hanging wall have 'south' polarity and give rise to positive (downward) vertical force at points on the ground above; the footwall has 'north' polarity and gives rise to a negative vertical force. The profile due to the top of the dyke alone will obviously be symmetrical, while the two profiles due to the sides will be similar in shape but of opposite sign; their intensity will diminish as the dyke approximates to the vertical. If the lack of symmetry between the two sides of the magnetic profile is not large, it follows that the effects due to the sides of the dyke are relatively small; under these conditions, since they are of opposite sign, the form of

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the symmetrical profile due to the top alone can be obtained with sufficient accuracy by taking the average between corresponding ordinates at an equal distance on either side of the maximum value[1] (broken line in Fig. 5).

The curve thus reduces to that for a simple magnetized strip[2] having the form and intensity of magnetization of the top of the dyke. If the depth below the surface is sufficiently large in comparison with the width of the strip, the profile is substantially the same as that due to a magnetized line, having a magnetization per unit length equal to the total magnetization per unit length of the strip, i.e., equal to iw, when w is the width and i the intensity of magnetization normal to the surface of the rock. The identification and measurement of such a feature affords one of the most precise methods available for ascertaining the depth of a concealed rock-surface. A magnetic ridge of this form may conveniently be termed a 'line-feature.'

Calculation of the magnetic profile above a magnetized line.—

(*a*) Force at a point near an infinite line.

With the notation of Fig 6: The force at P due to an element dx of the magnetized line OX is $I\,dx/r^2$ along XP, and its component along the normal OP is $\frac{Idx}{r^2}\cos\theta$, I being the intensity of magnetization per unit length of OX. From the figure, $dx\cos\theta = rd\theta$, and the force along OP becomes $Id\theta/r = -Id\theta\cos\theta/l$ (the force being that exerted by a *south* element on a *north* pole).

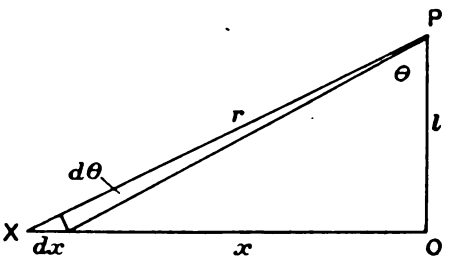

FIG. 6.—*Magnetic force at a point adjacent to a magnetized line.*

Integrating, the force f along OP is $-\int_0^{\theta}\frac{I\cos\theta}{l}d\theta = \frac{I}{l}\sin\theta$[3]. If the line extends to an equal distance on the other side of O, the horizontal components at P neutralize one another, and the total resultant force is directed along PO and has twice the above value.

For an infinite line, $\theta = \frac{\pi}{2}$ and $f = 2I/l$.

For a short line, when $\theta = 30°$, $f = I/l$.

[1] There is really a small displacement of the maximum, because the profiles of the sides are not quite symmetrical. The effect of the slope in the ground can be ignored at points near the maximum.

[2] A unipolar surface, not a magnetic shell.

[3] The sign of a *downward* force is made positive by convention.

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Thus half the force is due to the part of the line close to P. It follows that irregularities in the dykes at some distance from the traverse will have relatively little effect. To a first approximation the dyke may be treated as an infinite line if its length exceeds four times the depth.

(*b*) The magnetic profile.

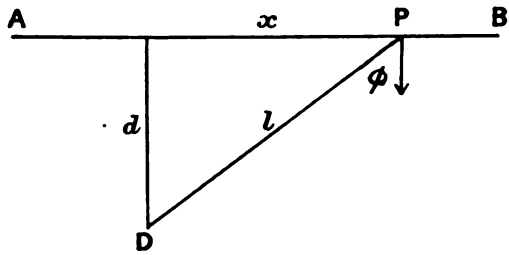

FIG. 7.—*To illustrate calculation of magnetic profile.*

The force calculated in paragraph (*a*) is directed toward the line. If the point D (Fig. 7) represents the trace of the line in a section at right angles to its length, and AB the line of traverse along which the observations are made, then with notation as in the figure the vertical force v at a point P in the traverse is given by

$$v = f\cos\phi = \frac{2I}{l}\cos\phi = 2I\frac{d}{d^2+x^2}$$

In this expression the ordinates are all proportional to I, so that a change in the nature of the rock will only alter the vertical scale without affecting the form of the profile. It follows that the depth can be calculated from the geometrical form of the profile even when the nature of the rock is unknown.

Expressing the ordinates as a fraction of the ordinate when $x=0$, i.e., $v_0=2I/d$, the general equation of the curves is $y=1/(1+a^2)$ where $a=x/d$.

From this (1) $\frac{dy}{da} = -(1+a^2)^{-2}.2a.$

(2) $\frac{d_2y}{da^2} = 4a\,(1+a^2)^{-3}.2a - 2(1+a^2)^{-2}.$

The maximum is therefore at $a=0$, i.e., $x=0$, while the point of inflexion is given by $d_2y/da^2 = 0$, i.e., $a^2 = \frac{1}{3}$, the co-ordinates being $x = d/\sqrt{3}$, $y = \frac{3}{4}$ (F in Fig. 8). The latter point can be identified by drawing the tangent of maximum slope; it lies rather near the apex and can be used to solve a profile where, for accidental reasons, the traverse cannot be completed. *Provided that the apex is known to be that of a simple line-feature profile,* d can be obtained from the value $d = \sqrt{3}\,x$ where x is the distance from the apex to the point of inflexion; or otherwise from the slope at the point of inflexion, where

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$\frac{dy}{da} = \frac{9}{8\sqrt{3}}$ and $\frac{dy}{dx} = \frac{9}{8\sqrt{3}d}$.[1] The direct method used below is preferable.

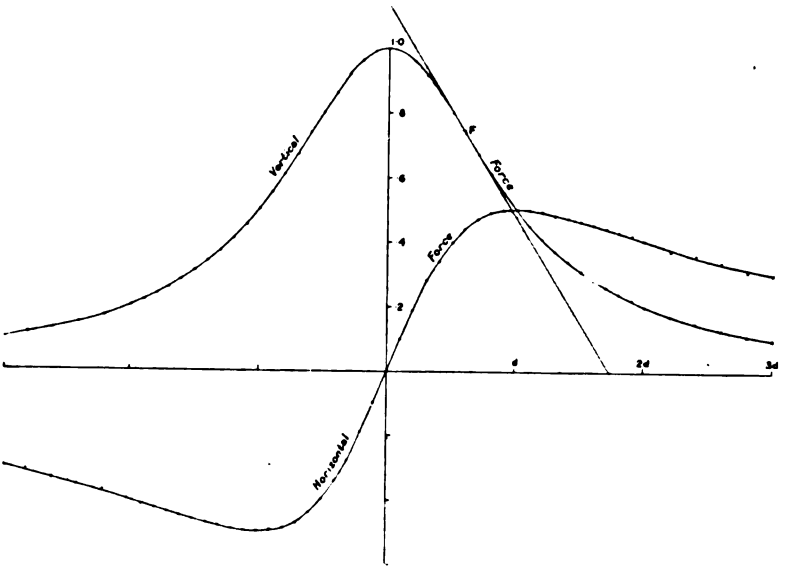

FIG 8.—*Calculated magnetic profiles for vertical and horizontal force across an infinite magnetized line at depth d.*

The calculated profile for an infinite line is given in Fig. 8. To verify the coincidence of an observed profile with the theoretical curve it is necessary (1) to identify the base-line of the anomaly, (2) to multiply the ordinates measured from this base-line by a factor so that the apex of the curve coincides with the apex of the theoretical curve, (3) to multiply the abscissae by a factor so that the curves coincide at one point, (4) to verify the coincidence of the curves throughout the profile. In the case of the Swynnerton Dyke the structure is known and the agreement may be accepted without special verification of each peak on the profiles.

The depth of the magnetized line below the line of traverse may be measured directly upon the profile as follows :—

The maximum force (at the apex where $x=0$) is $v_o = \frac{2Id}{d^2+x^2} = \frac{2I}{d}$.

At a point on the profile where $x=d$, the force is I/d. *Thus the depth of the dyke is equal to the horizontal distance (pq, Fig. 5) measured*

[1] The horizontal force profile may be derived in the same way, since $h = f \sin\phi = 2I\frac{x}{d^2+x^2}$. Its form is given in Figure 8. The maximum and minimum are at $x=d$, $x=-d$ and the maximum value is $h=I/d$. Dividing by the maximum of the v.f. profile, $v_o = 2I/d$, the general equation is $y = xd/(d^2+x^2) = a/(1+a^2)$ where $a = x/d$.

It will readily be seen that the horizontal force is less critically variable than the vertical force, and the profile is therefore not quite so useful for estimating a depth, which would be best obtained from the gradient at $x = o$.

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from the maximum of the magnetic profile to that point at which the vertical anomaly has diminished to one-half its maximum value. Measurements made upon several peaks in the Swynnerton traverses (Figs. 3 and 4) lead to the depths given in the table opposite, where the values are those for the equivalent narrow dyke. As the width becomes appreciable in comparison with the depth the profile begins to be wider than that for a narrow dyke, and the estimated depth will be too great. This effect only becomes noticeable when the width is greater than the depth, as will be seen in the following example where the calculated depths for the equivalent narrow dyke have been measured on the profiles for a known four-foot dyke that was surveyed as a test (see Fig. 2).

Traverse	Depth of equiv. narrow dyke (calc. from profile)	Actual depth (allowing 6 inches for soil, etc.)
I	5 feet	4 feet 6 inches
II	4 feet	3 feet 2 inches

Even in this extreme case the agreement is sufficient for practical purposes.

Calculation of width.—The maximum value of the anomaly is $v_o = 2I/d$. If the dyke is of similar material throughout (as appears to be the case for the narrow Swynnerton dykes), I, the total polarity per unit length, is equal to Vkw where V is the vertical component of the earth's magnetic field, k the susceptibility of the rock, and w the width of the dyke.

Taking again the test profiles in Fig. 2. V = 0·429 C.G.S.

Traverse	v_o Gamma	Depth	$\frac{1}{2} v_o d = I$ C.G.S.	Known width	$I/Vw = k$ C.G.S. $\times 10^{-5}$
I	300	4 ft. 6 in.	·205	4 feet	392
II	450	3 ft. 2 in.	·212	,,	405

The agreement is again sufficient. Rücker and White[1] found the value 236×10^{-5} for the susceptibility of material from the Swynnerton Dyke, but this came from Butterton and may be similar to the central part of the rock, which is less susceptible than the edges of the dyke (see traverses A, B, C, D, Fig. 3); or the rock surface may have a small permanent magnetization.

The width of the dyke in any profile can be calculated by the relation $w = I/kV = v_o d/2kV$; v_o is the maximum value of the anomaly in C.G.S.; d is the depth and w the width (measured with

[1] *Proc. Roy. Soc.*, 1898, vol. 63, pp. 464-466.

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the same unit). Accepting the value $k=400\times10^{-5}$ for the present rock, $w=0{\cdot}29\ v_0 d$. The values so calculated are summarized in the following table, the dykes in each traverse being indicated by *a*, *b*, *c*, from west to east.

CALCULATED DEPTH AND WIDTH OF THE SWYNNERTON DYKE.[1]

Traverse	Maximum anomaly (gamma)			Depth (feet below ground)			Width (feet)		
	a	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
A							200		
B							120		
C					Outcrop		70		
D							40		
E		258			12		12		
F		300	—		7	—	10	—	
G	—	270	260	—	5	11	—	7	12
H	45	45	—	31	21	—	4½	3½	—
I	30	60	—	48	16	—	4½	3½	—
J	300	180	120	1	4½	5	4½	4½	3
K	270	290	270	2½	3½	2½	5½	6½	5
L	120	120	90	4	8	1½	3	4	1½
M	18	90	150	20	6	5	1	3	4½
N	—	—		—	—		—	—	
O		—	30		—	11		—	1·3
P			30			6			·9

Traverse E is upon the same line as that made with the torsion balance. The depth 12 and width 12 correspond with depth 16 and width 20 deduced from the torsion balance observations. There is evidently a certain amount of drift or downwash covering the outcrop. The greatest cover, however, is met with under the alluvial

[1] Taken from the curves illustrated on a reduced scale in Figs. 3 and 4. Some traverses are not quite at right angles to the dyke and the depths and widths should be diminished by a factor $\cos\theta$, if θ is the deviation from the normal. For these small dykes the error is not important. In making measurements the curves are of course plotted on a much greater vertical scale than in Figures 3 and 4.

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flat between Yarnfield and the hill at Upper Heamies. In traverse H dyke *a* underlies the marshy floor of a small tributary hollow while in I the same dyke underlies the alluvium at the junction of the hollow with the brook. Here dyke *b* is also under the alluvium but corresponds with a marked ridge at the side of the valley a few yards away and is evidently nearer the surface. These depths strongly suggest the presence of a Glacial or pre-Glacial channel along the course of the present brook. The main valley about one mile to the south, near Norton Bridge, is occupied by considerable sheets of glacial drift, which account for the depths of 11 and 6 feet recorded in traverses O and P; it seems likely therefore that the alluvial flat at Yarnfield represents a shallow lake or marsh held up by the drift barrier.

The width of the dykes is consistent with that observed at the outcrop on Heamies ridge and indicates a gradual thinning out to the south. Traverses F and G indicate that the course of the dyke is a little to the east of the 'slight ridge' marked as dyke on the six-inch map; also that the dyke thins out on leaving the main ridge more rapidly than was indicated on the map. On the other hand the dyke at the top of the main ridge (traverses A and B) is evidently thicker than that shown on the map. Many small marl pits have been made in and near the southward extension of the dyke, perhaps with the hope of encountering the stone in bulk. It seems clear, however, that there is no hope of getting any substantial amount of this rock to the south of the main ridge where the present quarry is situated.

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VI.—THE TESCHENITE OF EASTER DALMENY

BY

SIR JOHN S. FLETT, K.B.E., F.R.S.

Plate VI

Text-figure 1

In the Lothians of Scotland 'whin sills' are of frequent occurrence. They form conspicuous features of the scenery, and are well known to mining engineers, as they are often penetrated underground in borings and sinkings. Geologists have mostly considered that they are of Carboniferous age and have divided them into two main classes, the teschenites and the quartz-dolerites. The teschenites contain olivine and analcite but no quartz; the quartz-dolerites contain quartz (or micropegmatite) and seldom olivine. There is little trace of transition between these classes, though a group of sills which has been studied by Dr. Campbell[1] contains olivine but not analcite; he has called them tholeiites. Descriptions of the mode of occurrence and petrography of these intrusions will be found in the memoir on 'The Geology of the Neighbourhood of Edinburgh' (*Memoirs of the Geological Survey*) and their outcrops are shown on the one-inch maps, Sheets 32 and 33, Scotland. In some cases teschenite is accompanied by picrite or by theralite, but quartz-dolerites and picrites are not found in the same sill.

In 1916 a boring was started at Easter Dalmeny, six miles west of Edinburgh, in search of the Dunnet Oil-shale by one of the mining companies that work the oil-shales of the Lothians. The bore is known as No. 2 Easter Dalmeny and a full journal is preserved in the Geological Survey offices at Edinburgh. The position of the bore is shown on the six-inch Geological Quarter-sheet, Linlithgow, 3 S.W., 2nd edit., 1921, 700 yds. E. of Dalmeny Church. At first the core was 2½ in. thick but it was subsequently reduced by various untoward happenings to 2 in., and finally to 1¼ in. After passing through about 27 ft. of 'surface,' which means soil, boulder-clay and rotten rock, it entered a firm teschenite and continued in that sill to a depth of 251 ft. Accordingly, the thickness of intrusive igneous rock met in the bore was 224 ft. It is important to note that the top of the sill is missing, as no Carboniferous sediments were passed through before the teschenite was encountered. A previous boring, however, situated about 350 yds. farther west, passed through 21 fms. of 'surface' and sediments, and then through 'whin' to 67½ fms. before again entering Carboniferous shale and sandstone. Accordingly, the full thickness of the sill in that boring was 46½ fms.

[1] Campbell, R., and J. W. Lunn, 'The Tholeiites and Dolerites of the Dalmahoy Syncline,' *Trans. Roy. Soc. Edin.*, vol. lv, 1928, p. 489.

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or 279 ft., and it seems quite possible that several fathoms of the top of the sill were missing in the No. 2 bore which is the one under description.

When the boring was in progress it was kept under observation by Mr. David Tait of the Geological Survey of Scotland, who collected specimens occasionally from the core. After a time it became evident that the teschenite showed interesting variations in composition, a very usual feature of the rocks of this group, and these were carefully watched. Subsequently on my instructions Mr. Tait took a typical set of specimens from the core at distances of 9 ft. apart, making 25 specimens in all, collected as accurately as possible. In addition to this set there are about sixty other specimens collected at various dates, and many of them with particulars of the depth of origin, but these are not regarded as being so generally reliable as the special series which was finally acquired.

The boring was carried out under war conditions and was subject to delays and irregularities. At about 40 fms. depth the diamond crown stuck in the whin and the bore was switched or diverted past the obstruction. The diameter of the core was reduced to 1¼ in. The Dunnet Oil-shale was found below the whin but it was in a 'burnt' condition and valueless. Finally the bore was carried to a depth of 72½ fms., but passed through no more whin below 42 fms. A general account of the geology of the district will be found in the Geological Survey Memoir on 'The Oil-Shales of the Lothians,' 3rd edit., 1927, p. 89. From the map and sections in that memoir it will be seen that there is a volcanic ash bed at Dalmeny village. This ash lies on the horizon of the Houston Coal, which is believed to be about 1,200 ft. above the Dunnet Shale. Possibly the teschenite sill is an intrusion belonging to that epoch of volcanic activity, and this may give an approximate estimate of its depth below the sea bottom at the time when it was intruded.

The specimens collected by Mr. Tait were pieces of core varying from one inch to three inches in length. They vary from three ounces to a pound in weight. The specific gravities were determined by weighing the whole specimen. The graph (Fig. 1, p. 61) shows the variation in specific gravity of the 25 specimens specially collected. Many of the 60 other specimens have also had their specific gravity determined but they are not inserted in the figure. For one thing these specimens were often taken to show interesting or slightly abnormal varieties of the rock; and moreover as they were not intended for the special purpose of this paper their position may not have been quite so accurately determined as that of the special series. It may be said, however, that, allowing for the presence of a few exceptional specimens, we may trace the same features in the results given by all specimens of which the approximate depth is known. The variations are principally due to the

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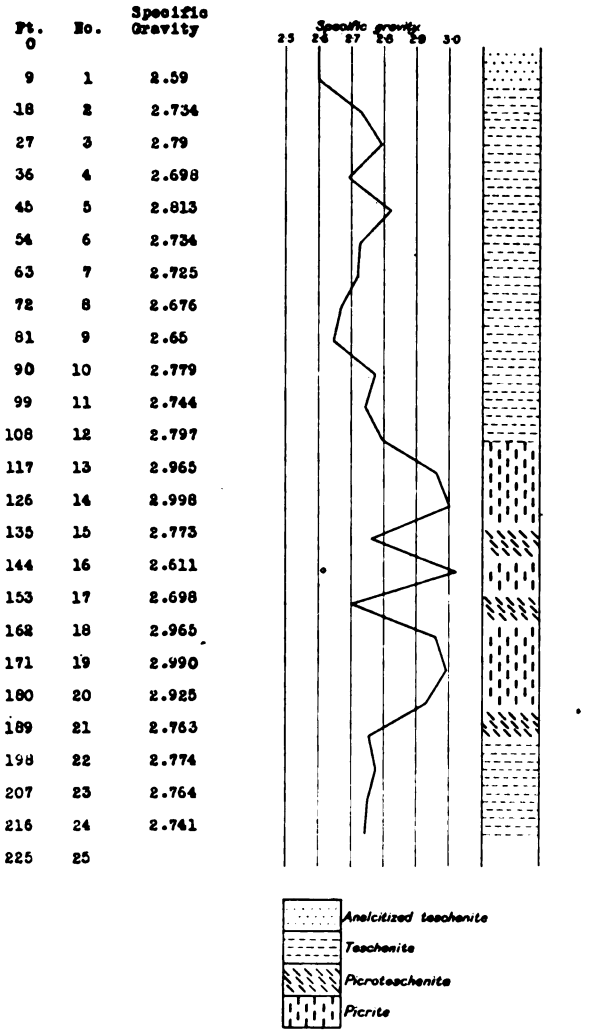

FIG. 1.—*The picrite-teschenite sill of Easter Dalmeny. Variation of specific gravity with depth from surface.*

occurrence of felspathic patches, light in colour and sometimes more coarsely crystalline than the average facies of the rock.

My object in having this collection made was to study the variation of density with depth. Much has been written on this question of recent years but except in a few cases there is a regrettable scarcity of exactly ascertained facts. A diamond bore through a thick sill furnishes evidence of a very reliable character and should yield more accurate results than measurements made on a natural exposure with weathered outcrops. The bore core is practically perpendicular to the surfaces of the sill (if the sill is nearly horizontal)

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and gives an opportunity of tracing every change and of referring every specimen to its correct position. Moreover the material, if not always fresh, is likely to be in better preservation than if collected from outcrops or quarries.

The teschenites of the Lothians are also rocks well suited for this test. They consist of olivine, augite, felspars and analcite. Among accessory minerals we may mention iron ores, apatite, and frequently hornblende and biotite, but these do not occur in great amount, and, with the possible exception of the iron ores, are not likely to affect the density of the rock. The minerals crystallize approximately in the order of decreasing density, viz., iron ores, olivine, augite, plagioclase, orthoclase, analcite. There is comparatively little magmatic resorption or assimilation, though where analcite occurs in great quantity the basic felspars are analcitized, sometimes completely, and hornblende and biotite may become conspicuous. Consequently, if we admit the hypothesis of differentiation by the sinking of heavy crystals, formed at an early period in a liquid magma, there seems no reason for not applying it to the case in hand. All the rocks consist of the same minerals in varying proportions. The heaviest rocks are picrites with much olivine, a less amount of augite, and felspar, and little or no analcite. The lighter rocks are rich in analcite and alkali felspar with augite and little olivine.

For our present purposes it is not necessary to give a complete account of the microscopic characters of the various types of rock that make up this core. There are, however, a few features of the petrography of these rocks that directly influence their specific gravities and these must be considered before we proceed to draw conclusions.

Pneumatolytic and Secondary Changes

The rock specimens when sliced and examined microscopically prove to be in a variable but seldom advanced stage of decomposition. Three processes may be recognized as having operated, viz., the production of analcite, serpentine, and carbonates.

In all the teschenites analcite is a characteristic mineral. Whether it should be regarded as primary or as secondary has been much discussed, but the matter is largely one of definition of terms.[1] It is important to recognize that in these rocks analcite occurs in two ways. Many slides show large irregular areas of analcite that obviously fill up the interspaces between the earlier minerals such as augite and felspar (Pl. VI, Figs. 1 and 3). This analcite is primary in this sense, that it is an original mineral of the rock and does not replace any other component. It frequently contains apatite and augite and sometimes stellate growths of chlorite or serpentine. The second kind of analcite occurs in veins, threads

[1] 'The Geology of the Neighbourhood of Edinburgh' (*Mem. Geol. Surv.*), 1910, p. 295; Scott, A., 'On primary Analcite and Analcitization,' *Trans. Geol. Soc. Glasgow*, vol. xvi, 1916, p. 34.

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and patches spreading through and replacing original felspar. Every stage of the process may be observed from incipient veining to complete substitution. Usually, however, a few shreds of the felspar remain and give an indication of the history of the mineral. This second type of analcite is due to pneumatolysis arising from the action of vapours or solutions containing soda or alkali silicates, at a late stage when the rock affected was already crystallized. This 'late' analcite is often full of chlorite, carbonates, etc., and sometimes chlorite rather than analcite is the principal mineral deposited. The action seems to have been accompanied by serpentinization of the olivine; for when analcite is abundant olivine is seldom or never fresh.

The original plagioclase felspars of the sill were soda-lime felspars ranging from a basic bytownite to oligoclase. In many of the rocks there is also much microperthitic alkali felspar surrounding the soda-lime felspar and occupying the intervening spaces. All these felspars may be replaced by analcite, partially or so completely that only traces of their original outlines remain (Pl. VI, Fig. 1). In this process the specific gravity of the rock is reduced, for the original plagioclase may have a specific gravity of 2·8 while that of the analcite is 2·4.

An examination of the rock-slices shows that analcitization is far more prevalent near the top of the sill. In some of these specimens more than half the felspar has disappeared. The more basic rocks from deeper situations have often very little analcite. Quite probably the pneumatolytic vapours forced their way outwards as the sill cooled and crystallized, and found an easier escape in an upward direction.

At the same time it is clear that the upper layers of the sill, to a depth of 30 ft. or so, were originally richer in felspar, and especially in alkali-silicates, than the deeper portions. Evidence of this is the frequent presence of well-formed though small crystals of bright green, slightly pleochroic aegirine-augite in the rocks of the upper levels. It accompanies the usual rosy-purple augite of these teschenites and is never very abundant, but it is a primary mineral and indicates the richness of these upper layers in silicates of the alkalis. Frequently a bright green colour characterizes a narrow external zone of the larger augite crystals, while the interior has the usual reddish-brown tints.

The second process that must be kept in mind is serpentinization of olivine. Some of the specimens are soft dark green serpentines easily carved by a pocket knife. They have a specific gravity of 2·6 and less; the microscopic slides show that they consist almost wholly of serpentine pseudomorphs after olivine (Pl. VI, Fig. 4). The original rock must have had a specific gravity of 3 or more, as the specific gravity of olivine is 3·3, while that of serpentine is 2·5. Many other specimens contain much olivine in an excellent state of

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preservation; it is not clear why a few specimens are so much decomposed but perhaps they have been in the vicinity of fissures or joints through which water circulated freely. In these rocks the felspar also is apparently entirely altered, while clear fresh crystals of augite may still be preserved in considerable numbers.

The third process that has affected the teschenite is carbonization. It is confined to a thickness of about six feet at the base of the sill. Below the teschenite some shaly beds were pierced which were recognized as the Dunnet Oil-shale in a burnt condition. In all cases where these sills intrude along the bedding of an oil-shale a part or the whole of the sill is converted into 'white trap.' The classic instance of this change occurs on the shores of the Firth of Forth, near the south end of the Forth Bridge, and has been described by several writers.[1] The change has been produced by the action of vapours emitted by the heated oil-shale, of which carbonic acid and volatile hydrocarbons were the principal.

The base of the Easter Dalmeny sill is represented by a brownish-grey compact rock that effervesces feebly with weak hydrochloric acid and proves on microscopic examination to consist of prismatic felspars in a mass of carbonates (Pl. VI, Fig. 6). The augite, which seems to resist the process of analcitization, has entirely vanished, though the outlines of its crystals and sometimes the pattern of the cleavages and enclosures are still recognizable. In the further stages of alteration the felspars also disappear, but traces of the original igneous structures may be identified, and their ghosts may be seen in the outlines of the carbonate masses. This change does not greatly alter the specific gravity of the rock.

Variation of specific gravity with depth

The specific gravities ascertained by weighing the hand specimens are shown in the curve in Fig. 1 on page 61. They exhibit considerable variety but in general the densest rocks are below the middle of the sill and the lightest are mostly near the top. But a cursory microscopic examination of the specimens proves that certain corrections are required. One of the lightest specimens is obviously a very basic rock, that consisted mainly of olivine and has been changed by decomposition to serpentine. Other rocks are much analcitized while the majority are in quite fair preservation.

As already stated the rocks belong wholly to the teschenite-picrite family that is so well represented in the Lothians. They present many very interesting petrographical features but these will not be described in full in this contribution. Similar rocks are well known to petrologists and have been investigated by several

[1] Stecher, E., *Tscher. Min. Pet. Mittheil.*, vol. ix, 1888, p. 145, and *Proc. Roy. Soc. Edin.*, vol. xv, 1888, p. 160; 'Geology of the Neighbourhood of Edinburgh' (*Mem. Geol. Surv.*), 1910, p. 311.

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investigators.[1] No completely fresh specimens of any members of this group have ever been met with in the Lothians and the secondary changes that they have all undergone may be ascribed partly to pneumatolytic processes and partly to ordinary weathering. Some of these have taken place very shortly after the consolidation of the rock; others are much later in development.

It would consequently be desirable to correct this curve by allowing for the amount and kind of alteration the original minerals have undergone. Unfortunately this is not possible except in a very general way. Chemical analyses showing the amount of combined water might be useful, but allowance would have to be made for the relative amount of analcite, serpentine, chlorite and other secondary minerals, and also for the specific gravity of the original felspar that has been replaced by analcite. Micrometric analyses do not seem to be applicable, especially to the analcite, as that mineral is often so irregularly distributed through the felspar that its areas could not be measured. On the whole, however, in the majority of cases the rocks are in a fairly similar state of preservation so that about equal corrections would have to be applied all round, and the relative positions and the general features of the curve would not be affected. The principal exception to that is specimen no. 16 which is a very basic rock entirely decomposed to serpentine. Its present density is 2·611. Its original density must have been over 3 as it probably contained more olivine (Plate VI, Fig. 4) than any other specimen that has been sliced. The corresponding alteration is indicated on the curve showing specific gravities. In the specimens taken near the top of the sill also allowance might be made for the great prevalence of analcitization which must have reduced their original specific gravity by about ·2. The general effect on most of the other specimens would probably not much exceed ·1. As this is so small and very great accuracy cannot be attained in any case it has been thought preferable to let the curve of actual densities stand unmodified except in the case of specimen no. 16. The Easter Dalmeny sill does not differ in important respects from other teschenite sills of the Lothians, of which descriptions are accessible in the literature. In this contribution we are interested principally in the distribution of density in relation to depth, and the explanations that may be advanced to explain it. As the density is dependent on the mineral composition of the rocks and on their state of decomposition, it is necessary to give a brief account of the microscopic characters of the specimens.

From the uppermost horizon (nine feet, and less, from surface) three specimens (26678, 26679, 19518) were sliced. They may be

[1] Geikie, A., *Trans. Roy. Soc. Edin.*, vol. xxix, 1880, p. 437; Allport, S., *Quart. Journ. Geol. Soc.*, vol. xxx, 1874, p. 529; Stecher, E., *vide sup.*; Teall, J. J. H., British Petrography, 1888, p. 191; Flett, J. S., 'Geology of Edinburgh' (*Mem. Geol. Surv.*), 1910, p. 293; Young, R. B., *Trans. Edin. Geol. Soc.*, vol. viii, 1905, p. 326; Campbell, R., and A. G. Stenhouse, *Trans. Edin. Geol. Soc.*, vol. ix, 1910, p. 121; Walker, F., *Trans. Roy. Soc. Edin.*, vol. liii, 1925, p. 361.

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described as analcitized teschenite. The grain size of the minerals is rather smaller than in the interior of the sill, the augite and felspar crystals being about 1 or 2 mm. in diameter, but the rock is not porphyritic and shows none of the characters of the fine-grained chilled edges of the teschenites. From this it is clear that at least 10 ft. of the top of the sill are missing, having been removed by denudation. The surface rock overlying the sill is presumably boulder-clay.

These analcitized teschenites consist of augite, biotite, olivine, felspars and analcite, with iron oxides and apatite. The olivine was scanty and is entirely represented by dark green clots of serpentine. The augite, on the other hand, is always perfectly fresh. It is seldom idiomorphic and shows zonal colours, the centres of the cystals being usually plum-coloured or purplish brown while a narrow margin is pale fawn and occasionally bright green. The biotite is dark chestnut brown and its crystals are fairly perfect. Little felspar is present, as the spread of analcite through the rock has been so complete that only shreds and patches of felspar remain (Pl. VI, Fig. 1). Some of the analcite may be 'primary' but by far the larger quantity replaces felspar, and traces of the outlines of the original crystals, with angular remnants of felspar here and there, conclusively demonstrate that the analcite is a replacement or substitution mineral. In these rocks there is often a considerable amount of alkali felspar and to this, and the abundance of analcite, their low specific gravity may be attributed.

The specimens taken from the 2nd to the 12th horizon, that is to say to a depth of 110 ft., or half way through the sill, may all be classed together as teschenites. They are more coarsely crystalline than those described above, and in the hand specimens often show long rude prisms of black augite that have irregular or indented borders, and may measure half an inch or even one inch in length. They are specially prominent in specimen 5 which consequently has a slightly higher specific gravity than the others. Under the microscope these large pyroxenes are not always simple but may be composed of several individuals clustered together. They have the usual range of colours, the centres being purplish brown, the edges fawn or greenish. Numerous lath-shaped sections of plagioclase felspar penetrate the outer portions of the large augites, but often do not reach their centres, and the outer ends of the felspar crystals usually project freely beyond the margins of the augites. The other components are olivine, not very abundant and always altered to dark green serpentine; much felspar, both plagioclase and orthoclase; and analcite filling angular interspaces and also pervading the felspars. The extent to which analcitization has gone on varies considerably but one frequently observes plagioclase crystals that have been penetrated through and through by analcite veins. Sometimes the centre is replaced by analcite while the outer zones remain. In other cases some crystals of felspar, though dull in

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appearance and seemingly decomposed, show their twinning and other original characters well preserved. The amount of alkali felspar in these rocks has often been considerable and is almost equal to the plagioclase. Biotite occurs in deep brown plates often attached to iron ores; the latter frequently form large networks and apparently are mostly ilmenite. In addition to analcite, and occurring usually in the same manner, various undetermined zeolites are common in these rocks.

The specimens taken from the 13th and 14th horizons (27390, 26685) are typical picrites (Pl. VI, Fig. 2) containing much olivine, which is in large measure fresh and bright. The olivine is in small rounded grains mostly less than half a millimetre in diameter. The crystals show incipient decomposition by the formation of magnetite and films of serpentine along their surfaces and cracks; occasionally they are completely decomposed to green and yellow serpentine. About one half of the rock consists of olivine. Pale brown augite is rather scanty, and never occurs as idiomorphic crystals but only as irregular masses that enclose many rounded grains of olivine. A good deal of fresh felspar is present forming a crystallized matrix that never shows crystalline outlines and encloses all the other minerals. The felspar is not zoned; it is twinned on both albite and pericline laws and has the optical properties of average bytownite, containing about 75 per cent. of anorthite. The rock contains no analcite and apparently no alkali felspar. Mention must also be made of the iron ores, which are not specially abundant, and of the chestnut brown biotite which very frequently is closely associated with the iron ores.

It is worthy of mention that in his original notes, taken in the field when the specimens were collected, Mr. Tait remarks that at the upper margin of the picrite there is a sudden change from a hard felspathic rock to a soft basic mass readily crushed in boring. There appears to be no transition zone as might have been expected on the theory of crystal settling.

This band of picrite is about 20 ft. thick and is underlain by about 10 ft. of a rock which we shall call picroteschenite. Mr. Tait noted that the transition from picrite to picroteschenite was gradual. This may be defined as a teschenite which is rich in olivine and poor in felspar and analcite: or less accurately, as a picrite in which felspar forms more than one half of the rock. The specimen sliced from horizon 15 (19522) is not specially rich in olivine; it has much augite which tends to occur as well formed crystals, and there is a large amount of felspar which for the most part shows definite crystalline outlines and is often zonal. The rock is accordingly more like a teschenite than a picrite in structure. Alkali felspar and analcite both are present but rather scarce.

At horizon 16 or 144 ft. from the top of the sill a rock occurs of very basic type (27391) but much decomposed. The microscopic sections prove that it consisted for the most part of olivine which

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is completely altered to serpentine (Pl. VI, Fig. 4). A little reddish augite is present, and its crystals are still fresh. It is difficult to make certain that there was no original felspar, but no trace of that mineral remains. A process of replacement of felspar by serpentinous secondary minerals can undoubtedly be recognized in certain microscopic slides from this sill. Hence it is unsafe to say that felspar was absent originally from this rock, but the amount that was present cannot have been large. In fact this rock seems to have been the most basic of the specimens that have been obtained from the boring. In its altered condition its specific gravity is 2·611 but in its original state it must have had the highest specific gravity of any part of the sill. Unfortunately we have no accurate record of the thickness of this picrite band as the rock was so soft that it was crushed by the weight of the boring tool and came out mostly as small fragments. It seems quite possible that at this level the bore was passing through a belt of broken rock that marked the position of a fault though there was no clear evidence of this owing to the broken condition of the core.

Specimen 17, taken at a depth of 153 ft., is again a picroteschenite (19523) not differing essentially from specimen 15. The abundant olivine is never fresh; the augite occasionally shows crystalline outlines and the felspar, which is almost entirely decomposed, forms nearly one half of the rock. There is a little analcite, and some radiate clusters of zeolites.

The next three horizons, 18, 19, and 20, are good picrites (27392, 26684, 27393) with much fresh olivine, a little augite and a fair amount of micropoikilitic bytownite as the last mineral to crystallize. The specimens are closely similar to those obtained at the 13th and 14th level and do not need special description. At the lowest level the felspars are beginning to show idiomorphic shapes and the rock is passing into picroteschenite. A curious feature of this slide is that several olivine crystals exhibit very perfect conchoidal and also radiating fractures (Pl. VI, Fig. 5). The presence of a little analcite may also be mentioned.

Specimen 21 is a picroteschenite (19524), basic and rich in decomposed olivine. Biotite also is conspicuous and the augite is partly idiomorphic. The felspars, often prismatic, are mostly clouded by decomposition and the rock as a whole is permeated with secondary products.

The next 20 ft. of the sill consist of typical teschenite (Pl. VI, Fig. 3) with scanty olivine (completely serpentinized), much augite and biotite (very fresh and often idiomorphic), and abundant felspar and analcite. Much of the felspar retains its characteristic optical properties and microscopic structure. The base of the sill does not show the complete analcitization that marks the specimens taken from the uppermost horizons, but in essential features this teschenite band is closely similar to the top half of the sill. The coarsely

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crystalline pyroxenes, however, are not found in this basal layer and ophitic texture does not make its appearance.

At horizon 24 we are within a few feet of the base of the sill and a complete change takes place in the character of the rocks. The vapours from the burnt oil-shale have acted strongly upon the igneous rock for a thickness of several feet and converted the teschenite into the 'white trap' of Scottish geologists (Pl. VI, Fig. 6). The characteristic mineral change is the replacement of augite (and olivine) by aggregates of carbonates, while the felspar, biotite and iron oxides remain unaltered. In the upper layers, where analcitization is dominant, the augite remains fresh while the felspars are destroyed. Consequently there is reason to believe that this basal horizon was never analcitized, or the felspars would not be so well preserved as they are. As the analcitization was going on during the cooling of the rock it seems clearly established that the formation of carbonates after pyroxene was also concurrent with the consolidation of the interior of the sill. Analcite is practically absent from the microsections taken from the base of the sill.

Sections taken from the actual margin of the igneous rock are very fine grained but not porphyritic and are completely decomposed. The underlying shale is obscurely spotted and has the characters of a spilosite.

Differentiation hypotheses

We shall now discuss how far the distribution of density in this teschenite sill and the petrological characters of its component rock varieties can be accounted for by the gravitational settling of early crystals of heavy minerals.

The average specific gravity of the lower half of the sill is evidently greater than that of the upper half, and the microscopic study of the rocks proves that this is due principally to the greater abundance of olivine and corresponding scarcity of felspar below the middle of the sill. As olivine has a high specific gravity (3·3), occurs in well-formed though never in large crystals, and was the earliest of the principal minerals to separate from the magma, there seems no difficulty in believing that its crystals would sink downward. Crystallization in a sill that is over 220 ft. thick must have lasted over a considerable time, and the teschenite magma, being richly charged with vapours, may easily be supposed to have had a low viscosity in the earlier stages of cooling.

If the magma was a homogeneous liquid at the time of its intrusion, with similar composition and density throughout, the first portion to enter the cleft in the Carboniferous sediments would be rapidly chilled and would show the mean density of the original magma. Unfortunately we are not in a position to form conclusions from the present state of the marginal rocks. The upper part of the sill has been very extensively and in some cases completely analcitized; this change is pneumatolytic and went on in a rock

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already crystallized. The effect of the replacement of felspar by analcite has been to reduce the specific gravity of the rocks possibly by about one-tenth. In the lower edge of the sill on the other hand the augite and olivine are replaced by carbonates, and the specific gravity may have been altered in consequence.

But near the base of the sill we have a thickness of about 20 ft. of teschenite which is quite similar in general characters to the teschenite of the upper half of the sill. This, then, may represent a comparatively rapidly crystallized mass; but a certain amount of olivine may be supposed to have sunk into this layer while the upper teschenite may be supposed to have lost some olivine. It is quite in accordance with this supposition that the lower teschenite as a whole has a specific gravity which is distinctly higher than that of the upper teschenite layer. On the average the difference is ·1 or ·15.

A rough estimation indicates that olivine is about three times as abundant in the lower half of the sill as in the upper. This would imply that one half of the olivine of the upper teschenite had subsided. It seems possible that some of the olivine in the upper half had disappeared during the crystallization and had been converted into biotite by magmatic assimilation or resorption, but on the whole biotite is not conspicuously more abundant in the upper teschenite than in the rocks that underlie it.

A curious feature, however, is that iron ores are about equally common in all parts of the sill: they do not seem to have been concentrated downwards by gravitation.

Augite also is not more abundant in the picrites than in the upper teschenite; as a matter of fact some of the teschenites about the 5th horizon are richer in augite than any other parts of the sill. We are at liberty to suppose that the augite of the teschenite crystallized at a rather later period when the rock was too nearly solid for the crystals to settle downwards. This is in agreement with the ophitic texture of some parts of the upper teschenite which would indicate that felspar began to crystallize at a period shortly before the main crystallization of the augite.

The picrite as described above contains a fair amount of felspar, and this is nearly all bytownite. Alkali felspar is absent. The high specific gravity of the picrites is partly due to their basic felspar.

Now if we imagine that the olivine crystals settled down into a liquid teschenite matrix we must account for the absence of alkali felspar. Analyses of Scottish teschenites show that they contain an approximate equal amount of anorthite and of albite plus orthoclase molecules. The picrite is not a teschenite enriched by precipitation of olivine but a bytownite-augite-olivine rock of distinct character. It is easy to imagine that an early crop of very basic plagioclase may have crystallized before the bulk of the augite and along with part of the olivine, and that this felspar sank into the

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picrite zone. But, while the olivine is in discrete crystals that not infrequently show fairly good crystalline outlines, the bytownite is never idiomorphic. It occurs as an interstitial crystalline cementing mass, enclosing olivine and all other minerals of the rock (Pl. VI, Fig. 2).

It is clear, then, that the bytownite crystallized from the liquid condition. A possible hypothesis is that lumps of bytownite formed at higher level, enclosing olivine grains, and these concretionary or nodular masses settled down. In that case, however, traces of the original bytownite-olivine nodules might be found in the picrite. They have not been observed, and in fact it is obvious from the microscopic slides that the picrite cannot have had this origin. We are driven to the conclusion that the felspar of the picrite crystallized in or near the horizons where it is now found.

Accordingly it seems necessary to admit that if the bytownite has sunk from above it has been melted up and has recrystallized. Now there is no difficulty in believing this. During the cooling of the sill the region of the picrite must have been the hottest of all for a long period. Heat would pass out into the cold rocks above and below the sill, and the cooling would gradually spread inwards towards the centre. For several reasons the heat would probably be discharged more rapidly in an upward direction, and the locus of highest temperature would be situated rather below the middle of the mass. Basic felspar that crystallized out in the cooler upper layers might be melted again when it sank. We are presuming that convection did not play an important role. In this way a layer rich in lime felspar might gradually form, and in the absence of stirring it might displace upwards the ordinary teschenite magma just as a strong solution of sugar gathers at the bottom of a cup of tea when it is not stirred.

Another process that was certainly at work may help to explain the disappearance of the alkali felspar from the picrite zone. It is clear that there has been an extensive migration of alkalis into the teschenite, as the felspars have been replaced by analcite through a considerable thickness of the rock. That process was pneumatolytic and was going on during the cooling of the upper layers. We are quite at liberty to suppose that at a late stage in consolidation alkali silicates were being distilled out of the centre of the sill and were being concurrently deposited in the marginal zones. If so, that process must have been completed before the picrite crystallized, as there is little trace of alkali felspar having been originally a component of the picrite.

On these assumptions it seems possible to explain in a general way the origin, position and characters of the picrite. The transitional zone of picroteschenite below the picrite might also be reasonably accounted for. There are, however, two picroteschenite bands in the picrite (Fig. 1, p. 61) and the process above outlined does not explain them. They are separated by a picrite band

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that is of very basic character. The sill accordingly has a banded structure. To explain this one might have recourse to a theory of veining, the picroteschenites being intrusions, but Mr. Tait, who collected the cores, got no evidence of intrusive junctions at these horizons. Still, if all the rocks were hot at the time of the intrusion of the picroteschenite such evidence might not be available.

On the other hand the banding might be due to fluxion. It is quite possible, for example, that a subsidence of part of the roof or the uprise of additional magma might set up displacements in the interior of the sill, and if part of the mass were still liquid, currents would result that would disturb the original distribution of the rock facies which form the sill. The two picroteschenites and their intervening picrite might represent an influx of magma already differentiated.

As a matter of fact a careful scrutiny of the cores shows that there is a certain amount of banding throughout the sill though it is never conspicuous. It must be remembered that the specimens described were taken as normal average specimens at distances of 9 ft. Many other specimens were taken, some of them because they seemed likely to be abnormal or interesting facies. Their characters generally agree quite closely with those of the standard specimens, but still they show a variation sufficient to prove that the mass is less uniform in character than might be supposed from the descriptions above given. It was, under the circumstances, impossible to ascertain whether these variations form bands of horizontal distribution or are quite irregular, and in any case they are not sufficient to affect the general argument which is all we strive to present in this contribution.

The general result at which we arrive from a study of the specific gravity and microscopic characters of the 25 specimens specially collected is that, if we can accept the theory that the alkali felspar has been eliminated from the picrite by the processes outlined above, the origin and position of the picrite are fairly well in accordance with what might be expected if differentiation resulted from the gravitational sinking of olivine crystals. The banding of the sill, however, cannot be thus explained and may indicate the injection of new differentiated magma, or fluxion movement in a partly differentiated mass.

LATER BASALT VEIN

A very interesting feature of the Easter Dalmeny bore remains to be mentioned. At a depth of approximately 36 ft. in the teschenite sill there is a small vein of fine grained black basalt about 4 inches thick. It has evidently crystallized rapidly, having been intruded after the teschenite into which it is injected had cooled down, though perhaps not completely, as in that case the basalt might have been glassy. The rock, however, is finely crystalline.

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It belongs to a fairly well defined and widespread group of Carboniferous basalts which was described and figured in the Edinburgh Memoir[1] as belonging to the Hillhouse type.

It contains numerous phenocrysts of olivine up to 1 or 2 millimetres in length, mostly in a state of good preservation, though occasionally converted into serpentine. There is no porphyritic augite but that mineral is the most important component of the groundmass in small, dark, reddish brown crystals, often showing idiomorphism. Felspar is rather less abundant than augite, as small transparent rods that seem to be mostly plagioclase of medium composition (andesine and labradorite). Iron ores are fairly common as irregular plates or well shaped octahedra. There is no biotite. No part of the groundmass has ophitic structure.

Between the minerals of the groundmass there are small areas of a clear, colourless, isotropic base, that may be a primary glass, but seems usually, where its areas are large enough for investigation, to have the properties of analcite. Small patches of analcite and zeolites, with sometimes pale green serpentine, are rather abundant; they have very irregular outlines and do not fill steam cavities but seem rather to be replacing the groundmass of the rock. As this rock is intrusive and has an analcite base some petrographers would prefer to call it a monchiquite (with accessory felspar) but it does not have the peculiar structures of the monchiquites.

It is clearly, however, a rock of Carboniferous type, and similar rocks are common in the Bathgate volcanic area, about ten miles to the west of Dalmeny; consequently, as it is intruded into the teschenite sill it strengthens the evidence for the Carboniferous age of that sill. Moreover, it proves that at Dalmeny, after the teschenite sill had cooled down, there was still liquid magma of very basic composition ready to rise to the surface when the opportunity offered. The specific gravity of this rock is 2·928; higher than any of the teschenites or picroteschenites, and almost as high as the picrites. In fact, both Watts and Hatch[2] have recognized the picrite affinities of this type of basalt. But if the rock had crystallized more slowly it would not have made a similar picrite to that of the Dalmeny sill, as it contains distinctly more augite than olivine; it might have resembled a very basic picroteschenite. If we regard this vein as representing the first arrival of a new series of injections from the same deep seated source as supplied the teschenite sill, then the new liquid magma did not correspond to the magma of the sill except in its general characters. It was distinctly enriched in augite rather than in olivine, and the augite was, so far as the evidence shows, completely in solution when the dyke was intruded.

[1] 'Geology of the Neighbourhood of Edinburgh' (*Mem. Geol. Surv.*), 1910, p. 320, and Plate xii, Fig. 6.

[2] Edinburgh Memoir, *loc. cit.*

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Description of Photomicrographs

Plate VI

Fig. 1. Teschenite (analcitized), Easter Dalmeny bore, Slide No. 19518, magnified 21 diameters, depth in sill 9 feet. Purplish-brown augite in fresh crystals nearly idiomorphic. Large opaque crystals of iron oxide. Lath-shaped felspars turbid and almost wholly replaced by analcite. On the left, above, an angular interspace filled with 'primary' analcite. The clear space on right of centre is a hole in the section.

Fig. 2. Picrite, Easter Dalmeny bore, Slide No. 27390, magnified 21 diameters, depth in sill 117 feet. Much olivine in rounded crystals, nearly fresh. On the left augite and on the right bytownite felspar forming a matrix without crystal outlines. Scanty iron ores and brown biotite.

Fig. 3. Teschenite, Easter Dalmeny bore. Slide No. 19525, magnified 21 diameters, depth in sill 198 feet. Rich in well-shaped reddish-brown augite crystals; felspar cloudy and partly analcitized; a large irregular area of clear analcite, enclosing augite and apatite needles.

Fig. 4. Picrite (decomposed), Easter Dalmeny bore, Slide No. 27391, magnified 30 diameters, depth in sill 144 feet. Olivine crystals entirely decomposed to serpentine; surrounded also by secondary products of doubtful origin. Scanty iron oxides.

Fig. 5. Picroteschenite, Easter Dalmeny bore, Slide No. 27393, magnified 21 diameters, depth in sill 180 feet. An olivine crystal showing concentric and radiating cracks. The rock is rich in olivine.

Fig. 6. Teschenite (white trap), Easter Dalmeny bore, Slide No. 19526, magnified 30 diameters; near base of sill. The outlines of augite crystals are visible, converted entirely into carbonates. The felspar is well preserved; no analcite. Biotite and iron ores are unaltered.

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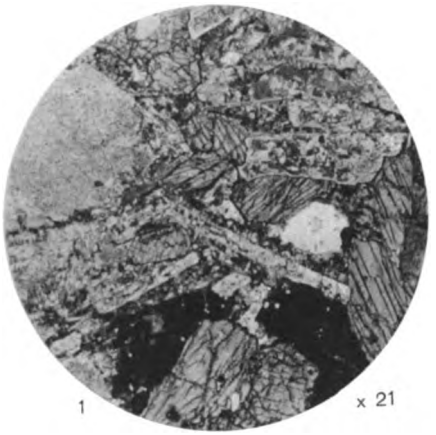

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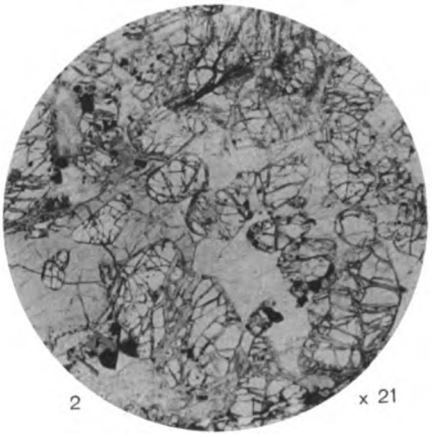

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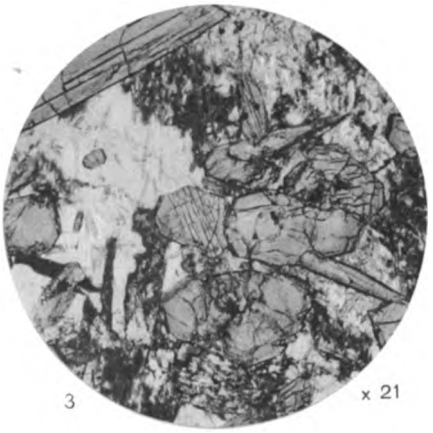

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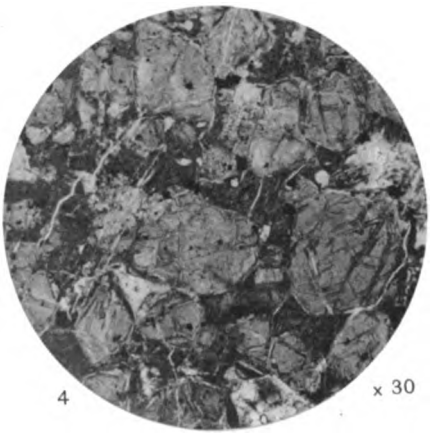

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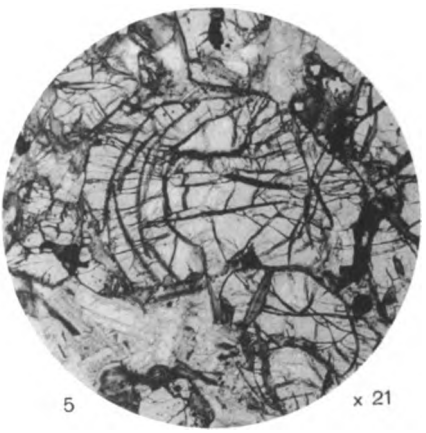

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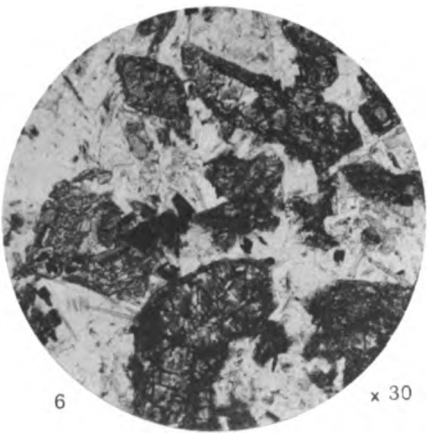

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TESCHENITE AND PICRITE: EASTER DALMENY.

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VII.—ON THE GONIATITE AND NAUTILOID FAUNA OF THE MIDDLE COAL MEASURES OF ENGLAND AND WALES

BY

W. S. BISAT, F.G.S.

Plates VII, VIII. Table A. Text-figure 1

The goniatite and nautiloid fauna of the Middle Coal Measures of England is a striking one, and a similar fauna occurs in the equivalent beds in Wales and on the Continent.[1]

The state of preservation of the fauna is generally poor, but the better preserved and more abundant material recently collected at the Cefn Coed Colliery in S. Wales by Mr. W. D. Ware, the Geological Survey, and Dr. A. E. Trueman, forms an important addition to our knowledge of the cephalopod life of the period.

It has long been known that in Staffordshire and elsewhere in the Midland Province the zone of *Gastrioceras* (G) is succeeded by measures with marine bands containing Pleuronautilids and goniatites of the genus *Anthracoceras*. This fauna is unknown in earlier beds except in a remarkable incursion at an horizon just below the floral break between Lower and Upper Carboniferous forms. This earlier incursion of a fauna consisting of Pleuronautilids and *Anthracoceras* occurs in the goniatite zone E, in England in the Sabden Shales of the Millstone Grit, and in Silesia in the Roemer marine band close to the summit of the Ostrauer Schichten. In Silesia this similarity of the goniatite fauna of the uppermost Ostrauer Schichten to that of the Coal Measures has led to the reference of these beds to the zone G. Thanks to the kindness of Prof. Dr. H. Schmidt of Göttingen I have been able to examine Silesian specimens of *Anthracoceras discus* Frech, and I am satisfied that this is the same species as *A. glabrum* Bisat, and that, to a first approximation, both species are the same as *A. paucilobum* (Phill.). This determination eliminates the discrepancy between the floral and faunal evidence in the Ostrauer Schichten, and renders the correlation of the English and German Coal Measure sequences much clearer. It would also appear that whilst there may be grounds for separating the Pleuronautilid of the Sabden Shales, *Tylonautilus nodiferus* (Armstrong), from the Pleuronautilid of the Ostrauer Schichten, *T. nodosocarinatus* (Roemer), as suggested by Pringle and Jackson,[2] the two species are merely local variants of the same stock.

In the Coal Measures of England and Wales we have evidence of at least three marine incursions with a cephalopod fauna of Pleuronautilids and *Anthracoceras*. The lowest is that of the 7 Foot Banbury

[1] Kukuk, P., 'Stratigraphie und Tektonik der rechtrheinisch-westfälischen Steinkohlenablagerungen' (Congrès de Stratigraphie Carbonifère, Heerlen, 1927, pp. 407-448), p. 436, Liége, 1928.

[2] Pringle, J., and J. W. Jackson, '*Tylonautilus nodiferus* gen. nov. . . . : a Carboniferous Guide Fossil,' *The Naturalist*, 1928, p. 373.

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marine band of N. Staffordshire (perhaps the equivalent of the Pennystone Ironstone of Coalbrookdale and the Catharina band of Westphalia), which occupies a stratigraphical position half-way between the Halifax (Crabtree, Alton) band and the Gin Mine band. The 7 Foot Banbury band is reported to yield *Pleuronautilus* and *Anthracoceras*,[1] and the Pennystone Ironstone is the type horizon of *P. falcatus* (J. de C. Sow.). The middle band does not appear to be synchronous in the Midland Province and S. Wales, where the lower band at Cefn Coed, whilst probably the equivalent of the Aegir band of Westphalia, suggests a slightly lower horizon than the Gin Mine and equivalent beds of the Midland Province.[2] The highest band, that of the upper marine band at Cefn Coed (=Cwmgorse band), contains the highest definitely known Carboniferous marine fauna of Western Europe, the band being possibly the equivalent of one of the higher bands of the Midland Province, but with a much better preserved fauna.

This wide goniatite zone, covering a thickness of 1,600 ft. of Coal Measures in Staffordshire, and more than double that thickness in Westphalia and Holland, deserves delimiting as a separate major zone A (=*Anthracoceras*) in the goniatite zonal sequence, capping the goniatite zone G (*Gastrioceras*), the dividing line being drawn beneath the 7 Foot Banbury band (see Table A). *Gastrioceras* continues to occur above this band, but only sporadically, as at the base of A at one colliery in Westphalia (*G. catharinae*), and rarely in the middle of A (*G.* aff. *globulosum* (Meek and Worthen)).

The stratigraphical horizon of the upper Cefn Coed (=Cwmgorse) band is 60 ft. below the Lower Pinchin Seam, and the lower Cefn Coed band is nearly 400 ft. below the Red Vein, there being 580 ft. of measures between the two bands, a similar thickness separating the Lady Coal marine band and the Gin Mine marine band of N. Staffordshire.

The cephalopod-fauna of these marine bands includes several forms either previously unknown or not differentiated from other species, and several new species are here described.

The highest band (Upper Cefn Coed=Cwmgorse) yields :—

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Homoceratoides kitchini *sp. nov.*

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[2] Perhaps it is the equivalent of one of the subordinate bands immediately under the Mansfield: see G. V. Wilson, 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, p. 141.

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Paper VII, Table A.

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	Lamellibranchs (Trueman)	Plants (Bertrand)
rdwick G	tenuis	
	phillipsi	N. scheuchzeri
op Marine ert (?) (Lady Coe		N. flexuosa
in, Mans	pulchra and similis	Lonchopteris bricei
Moss nnière (?)		
7 ft. Banb	modiolaris	Alethopteris lonchitica
	ovalis	
alifax Harassée		
Pot Cle		N. schlehani
Rough R(		
Shales		Pecopteris aspera
olcombe B		
Middle G		

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marine band of N. Staffordshire (perhaps the equivalent of the Pennystone Ironstone of Coalbrookdale and the Catharina band of Westphalia), which occupies a stratigraphical position half-way between the Halifax (Crabtree, Alton) band and the Gin Mine band. The 7 Foot Banbury band is reported to yield *Pleuronautilus* and *Anthracoceras*,[1] and the Pennystone Ironstone is the type horizon of *P. falcatus* (J. de C. Sow.). The middle band does not appear to be synchronous in the Midland Province and S. Wales, where the lower band at Cefn Coed, whilst probably the equivalent of the Aegir band of Westphalia, suggests a slightly lower horizon than the Gin Mine and equivalent beds of the Midland Province.[2] The highest band, that of the upper marine band at Cefn Coed (=Cwmgorse band), contains the highest definitely known Carboniferous marine fauna of Western Europe, the band being possibly the equivalent of one of the higher bands of the Midland Province, but with a much better preserved fauna.

This wide goniatite zone, covering a thickness of 1,600 ft. of Coal Measures in Staffordshire, and more than double that thickness in Westphalia and Holland, deserves delimiting as a separate major zone A (=*Anthracoceras*) in the goniatite zonal sequence, capping the goniatite zone G (*Gastrioceras*), the dividing line being drawn beneath the 7 Foot Banbury band (see Table A). *Gastrioceras* continues to occur above this band, but only sporadically, as at the base of A at one colliery in Westphalia (*G. catharinae*), and rarely in the middle of A (*G.* aff. *globulosum* (Meek and Worthen)).

The stratigraphical horizon of the upper Cefn Coed (=Cwmgorse) band is 60 ft. below the Lower Pinchin Seam, and the lower Cefn Coed band is nearly 400 ft. below the Red Vein, there being 580 ft. of measures between the two bands, a similar thickness separating the Lady Coal marine band and the Gin Mine marine band of N. Staffordshire.

The cephalopod-fauna of these marine bands includes several forms either previously unknown or not differentiated from other species, and several new species are here described.

The highest band (Upper Cefn Coed=Cwmgorse) yields :—

Metacoceras postcostatum *sp. nov.*
Cyclonautilus dubius *sp. nov.*
Anthracoceras cambriense *sp. nov.*
Homoceratoides kitchini *sp. nov.*

The Gin Mine and equivalent bands of North Staffordshire, Nottinghamshire, Yorkshire, and Lancashire yield :—

Metacoceras *aff.* cornutum (? *var.* sinuosum) Girty
,, costatum (*Hind*)
,, *cf.* perelegans *Girty*

[1] 'The Geology of the Country around Stoke-upon-Trent' (*Mem. Geol. Surv.*), 1925, p. 54.

[2] Perhaps it is the equivalent of one of the subordinate bands immediately under the Mansfield : see G. V. Wilson, 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, p. 141.

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Paper VII, Table A.

PROVINC	NON-MARINE ZONES	
	Lamellibranchs (Trueman)	Plants (Bertrand)
ardwick G	tenuis	
	phillipsi	N. scheuchzeri
op Marine bert (?) (Lady Coe		N. flexuosa
Gin, Mansf	pulchra and similis	Lonchopteris bricei
Moss nnière (?)		
7 ft. Banb	modiolaris	Alethopteris lonchitica
	ovalis	
alifax Harassée		
Pot Cle		N. schlehani
Rough R(		
Shales		Pecopteris aspera
olcombe B		
Middle G		

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Nautiloids, undetermined
Anthracoceras hindi *sp. nov.*
Dimorphoceras ?
Gastrioceras *aff.* globulosum (*Meek and Worthen*)
Homoceratoides jacksoni *sp. nov.* (found also in Skipsey's Band)

The Lower Cefn Coed band yields :—

Metacoceras *aff.* cornutum *Girty*
,, *aff.* costatum (*Hind*)
,, *cf.* perelegans *Girty*
Anthracoceras aegiranum *H. Schmidt*
Dimorphoceras ?
Gastrioceras *aff.* globulosum (*Meek and Worthen*)

PALAEONTOLOGY

GONIATITES

Anthracoceras Frech

This genus first occurs in Zone E (*A. paucilobum*) and there is one small species in Zone G (*A. arcuatilobum*). The three major species of Zone A probably mark three stages in the evolution of a single stock. At the Aegir horizon (Lower marine band, Cefn Coed) occurs *A. aegiranum*, with a comparatively narrow umbilicus and slightly convex flanks (Pl. vii, figs. 7, 8) ; in the Gin Mine band occurs *A. hindi* sp. nov. (' *Glyphioceras phillipsi* ' pars, Hind) with a much wider umbilicus and flatter flanks; whilst in the Cwmgorse or Upper marine band at Cefn Coed occurs *A. cambriense* sp. nov., a very compressed form, with transverse plications on the inner surface of the test, preserved in cast as scorings or striations in the Cefn Coed material.

Anthracoceras hindi sp. nov.

Plate viii, figs. 14-17.

This species is closely allied to *A. aegiranum*, with which it agrees in its ornament, which consists of slightly bundled delicate transverse striae. These striae are slightly bowed forward near the umbilicus, sweep in a backward curve on the flanks, and form a larger forward bow (lingua) at the latero-ventral shoulder. The hyponomic sinus is 7 mm. deep at 28 mm. diameter, which seems deeper than in *A. aegiranum*, for a Welsh specimen from the Lower Cefn Coed band (Ce 105, Dr. Trueman's collection) has a hyponomic sinus of 5 mm. at about 26 mm. diameter. The thickness is two-fifths to one-half of the diameter, and the umbilicus (including the inner area) is about one-sixth of the diameter, as against one-tenth of the diameter in *A. aegiranum*.[1] An early stage in the ontogeny is seen in specimens C27327 and C27329 (Brit. Mus. Coll.), from which it is clear

[1] *A. aegiranum* from the Lower Cefn Coed band occasionally shows this feature; see specimen Ce 119 in Dr. Trueman's collection.

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that at about 5 mm. diameter the ornament consists of strong umbilical plications or wrinkles, with delicate transverse striae between the major folds. In passing it may be noted that in two specimens of *A. aegiranum* from the Lower Cefn Coed band (Ce 124, 125, Dr. Trueman's collection) at 2 mm. diameter there exists a cruciformly arranged set of 2 to 4 constrictions per whorl. The internal cast is free from constrictions in the adult. The suture is seen in one young specimen only (C27329, Brit. Mus. Coll.) and follows the generic features in having a ventral lobe with divergent sides and low median saddle, broadly rounded ventral saddle, and open lateral lobe with a subacute tip.

Types: British Museum Collection, C 27326 (holotype); C 27327, C 27329 (paratypes).

Horizon: Gin Mine (=Twist) marine band, and equivalent bands in the Midland Province.

This species is usually preserved in the form of impressions in shale, but four well preserved solid specimens from Nettlebank (C27326-9, Brit. Mus. Coll.) and one from Sutton Boring, Notts. (AT4895, Geol. Surv. Coll.) are known.

I name this, the typical goniatite of the Gin Mine band, in honour of the late Dr. Wheelton Hind, in recognition of the great value of his pioneer researches in these beds.

Anthracoceras cambriense sp. nov.

Plate vii, figs. 5, 6.

This species is founded on a large number of fragmentary impressions from the Upper Cefn Coed (Cwmgorse) band. The umbilicus is as small as, or even slightly smaller than in *A. hindi*, and the conch is evidently more compressed, the thickness probably not being more than one-quarter to one-third of the diameter. The test ornament is similar in character to that of *A. hindi*, with an internal surface often smooth and polished, except that grooves are present following the general outline of the test-striae. These represent the casts of internal strengthening plications. A few originate near the umbilicus and others on the flanks, but they are most numerous and regular on the venter, where their casts form a series of deeply scored grooves. The species reaches a diameter of 60 mm.

Holotype: 49255 (Geol. Surv. Coll.). Paratype: 49257 (Geol. Surv. Coll.).

Other material: Ba 1556-1560, 1562, 1564, 1566, 1568, 1569, 1963, 1964 (Geol. Surv. Coll.); Ce 127, 130, 131, 136 (Dr. Trueman's collection). All specimens are from the Upper Cefn Coed (Cwmgorse) band, South Wales.

In the series *A. aegiranum*, *A. hindi* and *A. cambriense* there is a gradual decrease in the thickness of the conch, accompanied by an increase in the depth of the hyponomic sinus, two trends which often

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go hand in hand in Carboniferous goniatites. The large size of some specimens of *A. cambriense*, and the small size of *A. vanderbeckei* (Ludwig)[1] suggests that there is a gradual increase in size of the conch as one ascends the series, and there is some suggestion of a gradual elimination of the shallow bow in the test-striae near the umbilicus, which feature appears to be most marked in *A. aegiranum* and least in *A. cambriense*.

Anthracoceras aegiranum H. Schmidt

Plate vii, figs. 7, 8.

This species occurs in the Lower marine band, Cefn Coed Colliery, South Wales, as illustrated by specimens 49262, 49263 (Geol. Surv. Coll.).

Anthracoceras vanderbeckei (Ludwig)

Plate vii, fig. 9. Text-fig. 1c.

This is a small species (the largest English specimen I have seen being only 22 mm. in diameter), occurring in the 7 Foot Banbury marine band of Staffordshire, and the equivalent band of the Cheadle coalfield 74 ft. below the 4 Foot Coal. On the evidence of the ornament alone one would definitely refer it to the genus *Dimorphoceras*, but the suture lines of the solid specimens collected by Mr. J. T. Stobbs show characters transitional from *Dimorphoceras* to *Anthracoceras*. A series of shale-impressions from the Cheadle coalfield in the British Museum (C. 33302-8) show the ornament, and specimens of this character have been the basis of all determinations of *Dimorphoceras* from the Coal Measures of England.

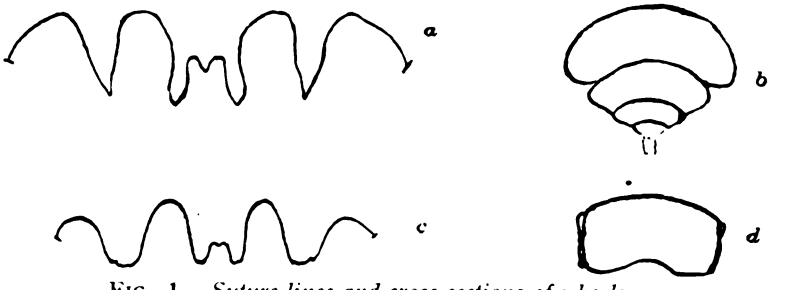

FIG. 1.—*Suture lines and cross-sections of whorls.*

a. *Gastrioceras* aff. *globulosum* (Meek and Worthen); suture line at 16 mm. diameter, × 3.
b. *Gastrioceras* aff. *globulosum*; cross-section of whorls, natural size.
c. *Anthracoceras vanderbeckei* (Ludwig); suture-line at 10 mm. diameter, × 4.
d. *Metacoceras* cf. *perelegans* Girty; cross-section of whorl, natural size.
Diagrams a, b, and d are from specimens obtained from the Gin Mine marine band, Staffordshire; c, from a specimen from the 7 Foot Banbury marine band, Staffordshire.

[1] I have noted below some English specimens of this species, which occurs abundantly in the marine horizon above the Catharina seam in Westphalia.

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Homoceratoides Bisat

This genus, originating in Zone H, continues to be represented by sporadic individuals in the marine bands at the top of R_1, throughout R_2, and with occasional very large specimens in G (Halifax Hard Bed horizon). The whole of the specimens in R_1, R_2, and G have been referred in the past to *H. divaricatum* (Hind) and require subdivision into separate species, but this cannot be attempted here. There is a generic tendency for the test ridges to become flat-topped, with the result that the hollows between the ridges become the dominant feature, and show as ridges on the inside of the shell, or as incised striations on the internal cast.

Rare fragments referable to this genus have been found in the Mansfield, Dukinfield, Skipsey's and Gin Mine marine bands, and these are now collected together and the species described, under the name of *H. jacksoni*, together with a later and better preserved species from the Upper Cefn Coed (Cwmgorse) marine band, *H. kitchini*.

Homoceratoides jacksoni sp. nov.

Plate vii, figs. 1, 2.

This species is founded primarily on two similar fragments of shale impressions, one from the Skipsey's marine band, and the other from the Mansfield marine band. The surface of the fragments is covered with very evenly spaced incised striations, with indications of a small well-marked bow near the umbilicus and a larger bow forming a lingua at the latero-ventral shoulder. With these two specimens I group several others from the Dukinfield marine band, the Gin Mine band, and the Lower Cefn Coed band. The outer test ornament is preserved on some of these, and shows rather strong transverse striations, with secondary spiral striations, the two producing a reticulate effect. The conch is a very compressed one, with a broad lingua and a not very deep hyponomic sinus. The ornament is weaker than that of *H. divaricatum*, from which it also differs in the presence of spiral striations.

The two first mentioned specimens are casts of the internal face of the shell.

Holotype: T861^D, Skipsey's marine band, Scotland (Geol. Surv. Coll., Edinburgh). Paratypes: AT 4879, Mansfield marine band, Sutton boring, Nottinghamshire (Geol. Surv. Coll.); 49264, Lower Cefn Coed marine band, South Wales (Geol. Surv. Coll.). Other material: L 9946, L 12050, Dukinfield marine band (Manchester Museum Coll.); C 33312, Gin Mine marine band, Nettlebank, Staffordshire (Brit. Mus. Coll.); Ba 1661, 1688, Lower Cefn Coed marine band, South Wales (Geol. Surv. Coll.).

The specimens L 9946 and C 33312, and the three from South Wales, show the spiral test-ornament, while L 12050 shows the outline of the conch and umbilical area.

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I have pleasure in naming this species after Dr. J. W. Jackson of Manchester, who collected the two specimens from the Dukinfield band, and to whose energetic field-work so much of our knowledge of the goniatites of the North of England is due.

Homoceratoides kitchini sp. nov.

Plate vii, figs 3, 4.

This species is founded on a number of brilliantly polished shale impressions from the Upper Cefn Coed marine band, South Wales. They are mostly small in size (up to 13 mm. diameter), though one fragment (Ba 1965) is of a much larger specimen of about 33 mm. diameter. The surface is ornamented in youth (at about 5 mm. diameter) with rather strong radial test striae, whose ends continue down the umbilical walls. With increasing age these become thin plications, which develop the form of the lingua and hyponomic sinus. In the adult the ornament (preserved as a cast of the inside face) shows similar regularly spaced incised striations, and a deep hyponomic sinus. The umbilicus, though small, is always open.

This species differs from *Anthracoceras cambriense* in the much greater regularity in the spacing of the striations and their continuance without variation in strength as far as the umbilical border. The lingua has a somewhat greater projection than that of *A. cambriense*..

Holotype: 49256 (Geol. Surv. Coll.). Paratypes: 49267, Ba 1565, 1570, 1572, 1966, 1967, 1968 (Geol. Surv. Coll.); Ce 132, 146 (Dr. Trueman's collection).

Horizon: All the specimens are from the Upper Cefn Coed (Cwmgorse) marine band, South Wales.

I have pleasure in naming this species after Dr. F. L. Kitchin, F.R.S., in recognition of the eminence of his researches in palaeontology.

Gastrioceras aff. *globulosum* (Meek and Worthen)[1]

Text-fig. 1, a, b.

The genus *Gastrioceras* is represented in the Middle Coal Measures by fragmentary specimens mainly from the Dukinfield marine band (Wild and Grundy Collections in the Manchester Museum), and it also occurs in the Gin Mine band and rarely in the Lower Cefn Coed band. A specimen from Staffordshire was figured by Hind (*Quart. Journ. Geol. Soc.*, vol. lxi, pl. xxxvi, fig. 1) under the name *G. carbonarium*. The imperfect fragments seen (especially W745, Manchester Mus. Coll.) show considerable resemblance to the American *G. globulosum* from the Upper Coal Measures of Springfield, Illinois, and Eastern Kansas. J. Perrin Smith records the species also from

[1] Meek, F. B., and A. H. Worthen, 'Descriptions of Invertebrates from the Carboniferous System,' *Geol. Surv. Illinois*, vol. ii, Palaeontology, Sect. 2, 1866, p. 390, pl. 30, fig. 2.

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the Middle Coal Measures of Scott Co., Arkansas, and the Upper Coal Measures of Texas (Cisco Formation). The surface ornament of the American specimens is unknown, but the Kansas specimen was stated by Meek and Worthen to possess ' faint traces of obscure nodes on the obtuse lateral angles of the whorls.'

In the British specimens referred to above, the umbilicus measures 9 mm. at 33 mm. diameter, and there are constrictions on the internal cast in the adult. In youth (and indistinctly in the adult) there are traces of beaded spiral lines on the tubercles, but the transverse test-striae are faint and nearly non-crenulate in the adult.

G. catharinae H. Schmidt,[1] with a beaded spiral test-ornament, is probably near this species, but appears to possess a larger lingua and is a more compressed form. It seems probable that with better preserved material, more spiral striations would be observed in the British specimens.

. Material: in the Manchester Museum, from the Dukinfield marine band, specimens W734, 745, 752 (Wild Coll.), L 9947 (E. W. J. Coll.), and unnumbered (E. Coll. Grundy) ; in the collection of the Geological Survey, from the Lower Cefn Coed marine band, Ba 1701 ; in the collection of Mr. J. T. Stobbs, from the Gin Mine band, Staffordshire, showing sutures and cross-sections of whorl (fig. 1).

Dimorphoceras ?

Shale impressions perhaps referable to this genus occur in the Gin Mine band. They show the well marked bow in the transverse striae near the umbilicus which is characteristic of the genus. There seems little difference between these specimens and specimens from the mut. β band of the Millstone Grit at Keighley, except that the Coal Measure examples seem more compressed. All these and also specimens from the Lower marine band at Cefn Coed Colliery (Ba 1680, 1683, Geol. Surv. Coll.) which I have referred provisionally to *Dimorphoceras*, may possibly be related to *Anthracoceras vanderbeckei*.

NAUTILOIDS

I do not propose to discuss here the genera *Ephippioceras*, *Solenocheilus* and *Coelonautilus*, which are absent in the South Wales material, although known to occur elsewhere in the Middle Coal Measures.

Metacoceras Hyatt

The genotype is *Metacoceras sangamonense* (Meek and Worthen),[2] from the Coal Measures of Illinois, a species with a quadrate cross-section of whorl and a single row of tubercles situated on the latero-ventral shoulder. The holotype unfortunately is only half a whorl

[1] Schmidt, H. ' Die carbonischen Goniatiten Deutschlands,' *Jahrb. der preuss. geol. Landesanstalt* (for year 1924), 1925, p. 598, Taf. 22, fig. 16 ; 26, fig. 18.

[2] *Geol. Surv. Illinois*, vol. ii, Palaeontology, Sect. 2, 1866, p. 386, pl. 29, figs. 3a, 3b, 3c.

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in extent and is without test-ornament. To this genus Girty has referred a series of species from the Wewoka formation of Oklahoma,[1] one species of which (*M. perelegans*) has a second row of tubercles situated on the umbilical border, and joined to the row of tubercles on the latero-ventral shoulder by slight ridges more pronounced in the younger portion of the conch, where they form strong ribs on the flanks. From this feature one deduces that there are considerable affinities between this species of *Metacoceras* and British Pleuronautilids of the group of *Pleuronautilus falcatus* (J. de C. Sow.), the species of which show a similar tendency to a double row of tubercles joined by costae. In the British species, however, the costae tend to be the dominant feature, and the tuberculation a secondary one.

In addition to this group of British Pleuronautilids there exists a series of small specimens from the Dukinfield band, the Gin Mine band and the Lower Cefn Coed band, consisting entirely of fragments of one small whorl, which may be referred not merely to this genus, but provisionally to two of the American species, *M. perelegans* Girty and *M. cornutum* Girty.

Metacoceras cf. *perelegans* Girty

Plate viii, figs. 7, 8. Text-fig. 1d.

With this species I compare provisionally the following specimens: Ba 1717, Ba 1719, Ba 1723, 49265, 49266, Geological Survey Collection, from the Lower Cefn Coed marine band.[2] Of the five cited fragments from Cefn Coed, 49266, whilst showing only a quarter of a young whorl, exhibits clearly the depression along the central axis of the venter and the hyponomic sinus as figured by Girty (*op. cit.*, pl. xxx, fig. 6). Ba 1723 (which can only be doubtfully compared with this species) shows the umbilical wall. The tuberculate costae of the Welsh specimens are backwardly directed, and this feature serves to distinguish them from specimens of the *M. falcatum* group.

Three solid specimens in the collection of Mr. J. T. Stobbs, from the Gin Mine marine band, Staffordshire, show that in the British form the cross-section of the whorl is much wider than in the American species (see text-fig. 1d), and this feature is shown also in specimen LT 1721 (Geol. Surv. Coll.) from the Dukinfield marine band. It seems improbable, therefore, that the English and American specimens are of the same stock.

Metacoceras aff. *cornutum* Girty

Plate viii, fig. 9.

Under this species I range specimen Ba 1718 from the Lower Cefn Coed band (Geol. Surv. Coll.), which shows one row of tubercles

[1] Girty, G. H., 'Fauna of the Wewoka Formation of Oklahoma,' *U.S. Geol. Surv., Bull.* 544, 1915, pp. 239-246, pls. xxix-xxxi.

[2] Compare also a specimen ascribed by Hind to Crick's *Pleuronautilus pulcher*, from 71 ft. below the Four-Foot Coal, Cheadle. See *Quart. Journ. Geol. Soc.*, vol. lxi, 1905, p. 541, pl. xxxvi, fig. 3.

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at the latero-ventral shoulder, and an acute edge to both the venter and umbilicus. A very similar specimen in the Manchester Museum (L 12051, E. Coll., J. W. Jackson, from the Dukinfield marine band) shows a rounded umbilical edge, and may represent Girty's variety *sinuosum*. See also specimen C 33299 in the British Museum Coll., from Nettlebank, Staffordshire.

The species differs from *Temnocheilus carbonarius* Foord in that the tubercles are situated on the flanks, and not as in that species forming spout-like projections from the edge of the venter.

Specimen LT 1735 (Geol. Surv. Coll.), from the Dukinfield marine band, shows nearly a complete whorl of apparently the same species, and suggests that this form is much more compressed than the English specimens referred to the previous species.

Group of *Metacoceras falcatum* (J. de C. Sow.)—*costatum* (Hind)—*postcostatum* sp. nov.

Plate vii, figs. 10-12 ; viii, figs. 1-6.

These three species appear to form three stages in the evolution of a single gens. In this group of large Pleuronautilids the umbilical slopes are at an angle of about 45° and free from costae. The costae on the flanks increase in number per whorl with the size of the individual, but show a reduction in number in the later as compared with the earlier forms. The body chamber occupies about one quarter of a whorl and is frequently preserved as a separate solid specimen, with a venter which is flat except in *M. postcostatum* (see Ba 1971). The sutures have been seen in *M. falcatum* and *M. postcostatum*. I am informed by Dr. Trueman that above the horizon of *M. falcatum* in Coalbrookdale (Pennystone Ironstone) is a wide range of *Carbonicola*, and I follow him in regarding this horizon as a low one, much below the Mansfield or Gin Mine band.

We therefore get the following ascending sequence of species :—

(1) *M. falcatum* (J. de C. Sow.) (Pl. viii, figs. 4-6), with quadrate cross section of whorl (as wide as high), costae numerous and often arcuate (9 to 10 in a quarter-whorl at 15-20 mm. height of whorl), from the Pennystone Ironstone of Coalbrookdale.[1]

(2) *M. costatum* (Hind) (Pl. viii, figs. 1-3), with cross section as above, costae less numerous (6-7 in a quarter-whorl at 15-20 mm. height of whorl) but stronger, linear and forwardly directed, with a pronounced forward hook at the latero-ventral margin, developing into a strong tubercle in the adult. At maturity the venter is flat, and sunk below the scalloped and tuberculate rim of the flanks. This feature is best seen in a specimen from the Dukinfield band in the Manchester Museum (Wild Coll. 731), where the tubercles form the crests of a raised pleated rim on the edge of the flat venter

[1] *Pleuronautilus carbonarius* Kruglov, from horizon C_3^{c+d} in the Urals, has similar ornament, but wider cross-section of whorl. See *Trav. Mus. Géol. Leningrad*, iii, 1928, pl. xi, fig. 10.

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(Plate viii, fig. 1). The species occurs in the Gin Mine, Mansfield and Dukinfield marine bands, and one rather poor specimen is recorded from the Lower Cefn Coed marine band of South Wales.

(3) *M. postcostatum* sp. nov. (Plate vii, figs. 10-12), with a whorl section slightly wider than high (32 mm. : 28 mm.); costae 5 in a quarter-whorl at 15-20 mm. height of whorl, and somewhat more forwardly directed than in *M. costatum*; tubercles obsolescent; venter at maturity not sunk below rim, and slightly convex. The cross-section of the adult whorl is reminiscent of *M. cornutum* Girty (*op. cit.*, Pl. xxix, fig. 5b). The test-ornament is imperfectly preserved, but consists of close transverse striae (see 49259, 49261, Geol. Surv. Coll., and Ce 140, 153, Dr. Trueman's collection) slightly forwardly projected at the junction with the preceding whorl, but gradually curving backwards to pass over the flanks in a backward direction, crossing the costae at an angle of about 45°. The hyponomic sinus has not been seen but is probably deep. Obscure traces of spiral striae are seen on the umbilical walls of the inner whorl of specimens 49261 and Ce 154, and on the flanks of Ba 1577.

The suture line both of *M. falcatum* (C 33347, Brit. Mus. Coll.) and *M. postcostatum* (Ce 129, Dr. Trueman's collection) is the same as that of *M. cornutum* as figured by Girty (*op. cit.*, Pl. xxix.).

Holotype: 49261 (Geol. Surv. Coll.). Paratypes: 49258, 49259 (Geol. Surv. Coll.); Ce 129 (Dr. Trueman's collection). Other material: Ba 1583, Ba 1971 (Geol. Surv. Coll.); Ce 140, Ce 153 (Dr. Trueman's collection).

Horizon: all material is from the Upper Cefn Coed (Cwmgorse) marine band, South Wales.

Additional species of this group are *M. armatum* (J. de C. Sow.), from the Pennystone Ironstone, and *M. rotifer* (Salter), from the Dukinfield marine band, both based originally on solitary specimens. *M. armatum* may perhaps represent an aberrant individual of the main species.

Metacoceras rotifer (Salter)

A second specimen of this species is to hand from the Dukinfield marine band, showing fragments of the transverse test-ornament and the closely spaced costae crossing the striae obliquely (specimen LT 1707, Geol. Surv. Coll.). Salter's holotype (11371, Geol. Surv. Coll.) shows about 13 costae in a whorl at 15-20 mm. height of whorl, as against 9 to 10 costae in *M. falcatum*, and less in the other species. The holotype has the costae radial, but in the second specimen, at an earlier stage of growth, they are forwardly directed.

Cyclonautilus dubius sp. nov.

Plate viii, figs. 10-13.

Under this name I group a series of very variable non-costate nautiloids from the Upper Cefn Coed marine band, with rounded

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whorls (sometimes flattened, as in 49260) and nearly vertical umbilical walls, with an umbilicus about one-third of the diameter. Width of whorl variable, from about equal to the height to about twice the height of whorl. Transverse test-striae close and thread like (49260, Ba 1584), radial or bent backwards on the flanks and with a deep hyponomic sinus. Occasional vague spiral lines are visible on specimen Ce 135. Sutures very slightly (Ce 141) or broadly sinuous (49260).

There may be two or more species included in these forms. Specimen Ba 1970 has a highly arched whorl-section, whilst Ce 135 and Ce 141 have broad venters. The individual 49260 has more sinuous septa than the other specimens.

The generic affinities of this species are uncertain, but the suture line is similar to that of *Cyclonautilus umbilicatus* Hind, from which *C. dubius* differs in having a much larger umbilicus.

One or more of the species described by Kruglov from the Urals resembles this species. Compare, for instance, *Domatoceras minimum*[1] from the Upper Carboniferous (C_3^{c+d}), and *Coloceras* (?) *sarvaense*[2] from the Artinskian (CP_g).

Holotype: 49260 (Geol. Surv. Coll.). Paratype: Ce 141 (Dr. A. E. Trueman's collection). Other material: Ba 1578, 1579, 1584, 1970, 1972 (Geol. Surv. Coll.); Ce 135, 137, 144, 148 (Dr. Trueman's collection).

Horizon: all material is from the Upper Cefn Coed (Cwmgorse) marine band, South Wales.

The nautiloid fauna is obviously closely allied to that recorded by Girty from the Wewoka Formation of Oklahoma, and the more recently described fauna from the Urals recorded by Kruglov.[3] A species described by Kruglov, *Pleuronautilus* (?) *kasarmenskensis* from the Upper Carboniferous (C_3^c) shows considerable ornament-resemblance to *Metacoceras postcostatum*, but the text-figure shows it to have a more highly arched whorl-section. The horizon of the Russian specimens is presumably much higher than our Middle Coal Measures, but the exact correlation of the Carboniferous beds of Western and Eastern Europe is still in its infancy. Similarly, the relations of the Wewoka Formation and our Middle Coal Measures are uncertain, but they would appear to be fairly close.

Temnocheilus carbonarius Foord

The holotype of this species came from Coalbrookdale, presumably from the Pennystone Ironstone. A second specimen is from 70 ft. below the 4 Foot Coal of Cheadle (C 33300, Brit. Mus.

[1] *Trav. Mus. Géol. Leningrad*, iii, 1928, pl. xiii, figs. 6-26.

[2] *Op. cit.*, pl. v, figs. 10-12.

[3] M. V. Kruglov, 'Upper Carboniferous and Artinskian Nautilidae of the Urals' [Russian, with English Summary], *Trav. Mus. Géol. Leningrad*, iii, pp. 63-206, figs., and pls. v-xv, 1928.

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Coll.). This is the only specimen I have been able to trace, and it carries with it some suggestion of the contemporaneity of the two bands mentioned.

I am much indebted to the officers of the Geological Survey, of the British Museum (Natural History), and of the Manchester Museum, and to Dr. A. E. Trueman, for the loan of many of the specimens on which this paper is based. I desire also to thank Mr. J. T. Stobbs for the loan of specimens, and for information regarding the equivalence of the 7 Foot Banbury marine band and the band situated 70 ft. below the 4 Foot Coal of Cheadle.

In preparing the photographs for Plates vii and viii in the laboratory of the Geological Survey, Mr. J. Rhodes, junr., has accomplished a difficult task with much skill.

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Explanations of Plates VII and VIII

In all cases the register-numbers of the specimens are cited. The specimens bearing the numbers 49255 to 49267 are in the collection of the Geological Survey in London.

PLATE VII

Fig.

1. *Homoceratoides jacksoni* sp. nov., holotype, × 2. Skipsey's marine band, railway-cutting nearly half-a-mile south of the railway station, Motherwell, Scotland. Geol. Surv. Coll., Edinburgh, T 861D.
2. *Homoceratoides jacksoni* sp. nov., paratype, × 2, showing secondary spiral linear ornaments of the outer test. Lower marine band, Cefn Coed Colliery, South Wales, 49264.
3. *Homoceratoides kitchini* sp. nov., holotype, × 2. Upper marine band, Cefn Coed Colliery, South Wales, 49256.
4. *Homoceratoides kitchini* sp. nov., paratype, × 2, showing ornament in the adult. The same horizon and locality, 49267.
5. *Anthracoceras cambriense* sp. nov., holotype, × 2. Upper marine band, Cefn Coed Colliery, South Wales, 49255.
6. *Anthracoceras cambriense* sp. nov., paratype, × 2. The same horizon and locality, 49257.
7. *Anthracoceras aegiranum* H. Schmidt, × 2. Lower marine band, Cefn Coed Colliery, South Wales, 49262.
8. *Anthracoceras aegiranum* H. Schmidt, × 2. The same horizon and locality, 49263.
9. *Anthracoceras vanderbeckei* (Ludwig), × 2. Marine band 74 ft. below the 4 Foot Coal, Cheadle Coalfield. Brit Mus. Coll., C33304.
10. *Metacoceras postcostatum* sp. nov., holotype, natural size. Upper marine band, Cefn Coed Colliery, South Wales, 49261.
11. *Metacoceras postcostatum* sp. nov., paratype, natural size. The same horizon and locality, 49259.
12. *Metacoceras postcostatum* sp. nov., paratype, natural size. The same horizon and locality, 49258.

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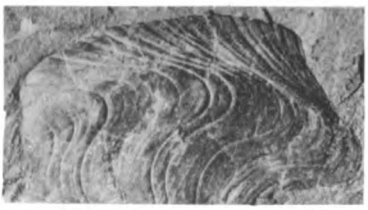

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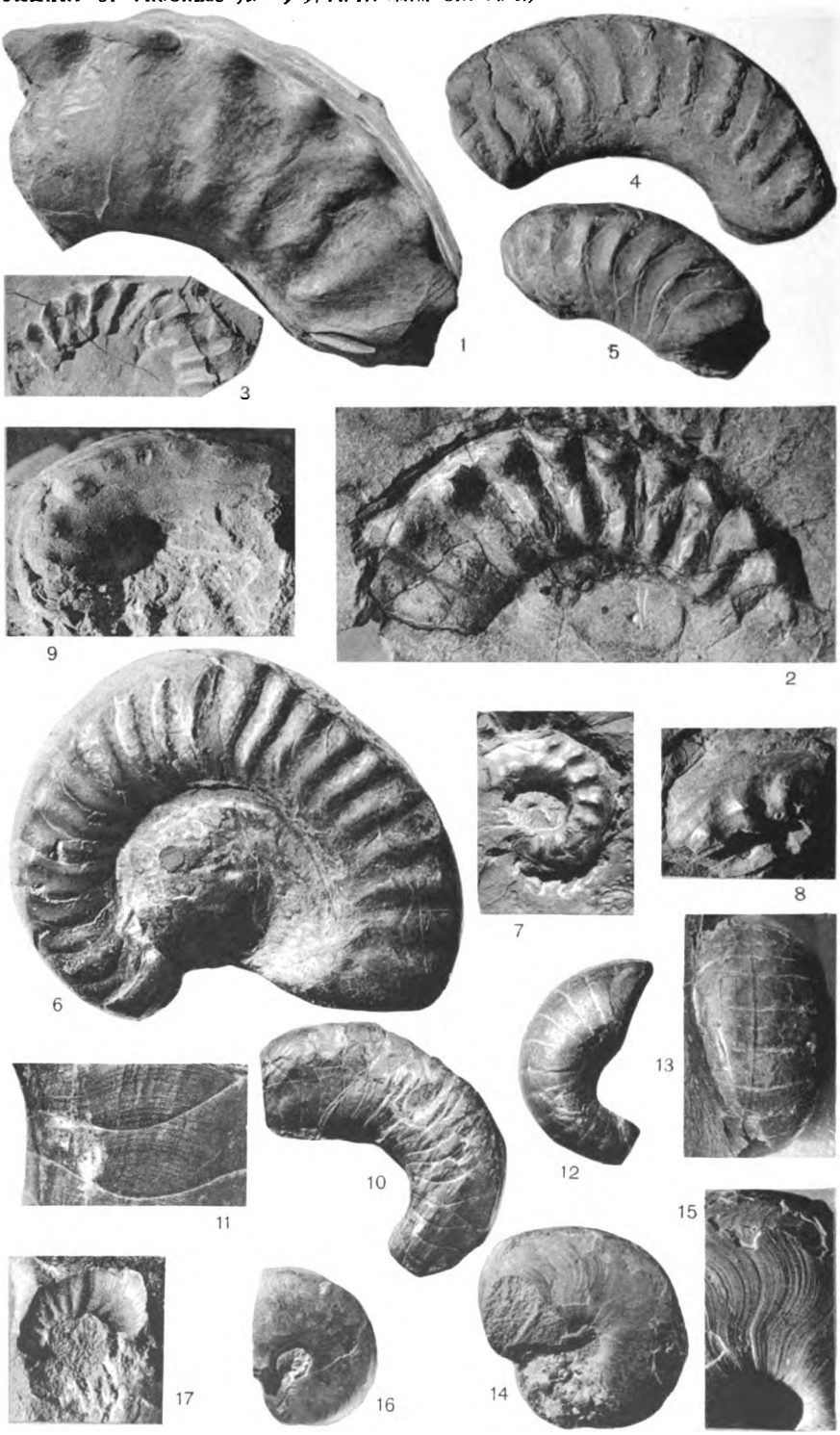

GONIATITES AND NAUTILOIDS FROM THE COAL MEASURES.

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PLATE VIII

Fig.

1. *Metacoceras costatum* (Hind), natural size, showing the ornament on the adult body-chamber. Dukinfield marine band, Ashton Moss Colliery, Lancashire. Manchester Museum, W731.

2. *Metacoceras costatum* (Hind), natural size, showing the ornaments at an earlier stage than is seen in fig. 1. Gin Mine marine band, Nettlebank, Staffordshire. Brit. Mus. Coll., C33295.

3. *Metacoceras costatum* (Hind), natural size, showing adolescent ornament. The same horizon and locality, Brit. Mus. Coll., C33294.

4. *Metacoceras falcatum* (J. de C. Sow.), natural size. Pennystone Ironstone, Coalbrookdale, Shropshire. Brit. Mus. Coll., C.4685.

5. *Metacoceras falcatum* (J. de C. Sow.), natural size. Same horizon and locality, Brit. Mus. Coll., C469a.

6. *Metacoceras falcatum* (J. de C. Sow.), natural size. Same horizon and locality, Brit. Mus. Coll., C33346.

7. *Metacoceras* cf. *perelegans* Girty, natural size. Lower marine band, Cefn Coed Colliery, South Wales, 49265.

8. *Metacoceras* cf. *perelegans* Girty, × 2. The same horizon and locality, 49266.

9. *Metacoceras* aff. *cornutum* (? var. *sinuosum*) Girty, × 2. Dukinfield marine band, River Tame, Dukinfield, Lancashire. Manchester Museum, L12051.

10. *Cyclonautilus dubius* sp. nov., holotype, natural size. Upper marine band, Cefn Coed Colliery, South Wales, 49260.

11. *Cyclonautilus dubius* sp. nov., portion of the holotype (49260), × 4, showing details of the ornament.

12. *Cyclonautilus dubius* sp. nov., paratype, natural size, lateral view. Upper marine band, Cefn Coed Colliery, South Wales. Dr. A. E. Trueman's collection, Ce 141.

13. *Cyclonautilus dubius* sp. nov., natural size. Ventral view of the specimen shown in fig. 12.

14. *Anthracoceras hindi* sp. nov., holotype, natural size. Gin Mine marine band, Nettlebank, Staffordshire. Brit. Mus. Coll., C27326.

15. *Anthracoceras hindi* sp. nov., portion of the holotype (C27326), × 2, showing details of the ornament.

16. *Anthracoceras hindi* sp. nov., paratype, natural size. Gin Mine marine band, Nettlebank, Staffordshire. Brit. Mus. Coll., C27329.

17. *Anthracoceras hindi* sp. nov., paratype, × 4, showing ornament in early adolescence. Same horizon and locality. Brit. Mus. Coll., a fragmentary impression on specimen C27327.

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